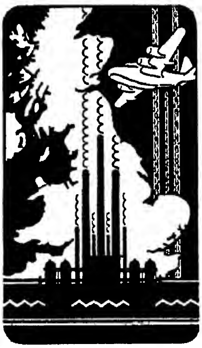
THE SECRETS OF OTHER PEOPLE'S JOBS

THE STORY OF GREAT BRITAIN'S INDUSTRIES AND THE WORKERS WHO MAN THE MACHINES



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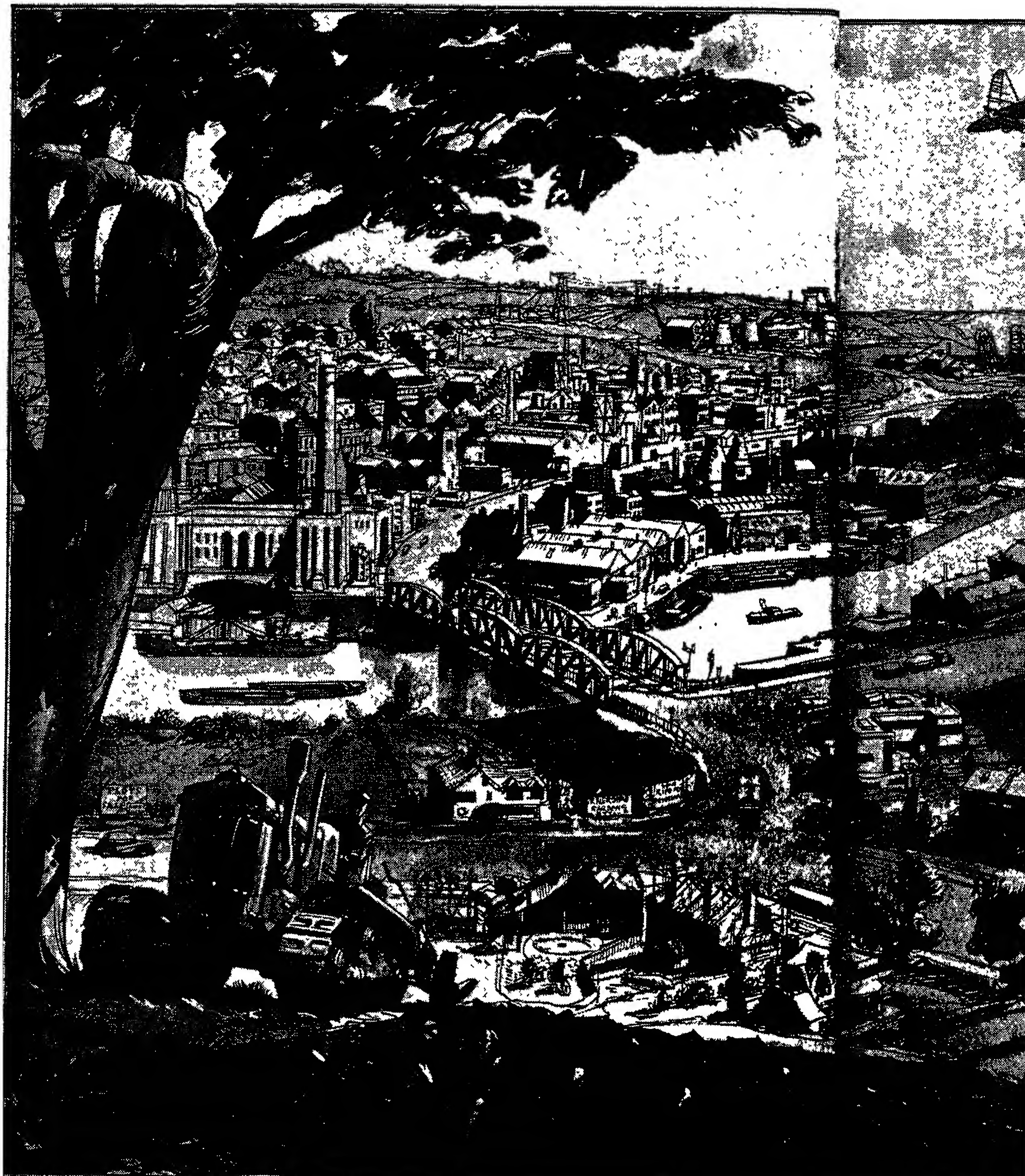

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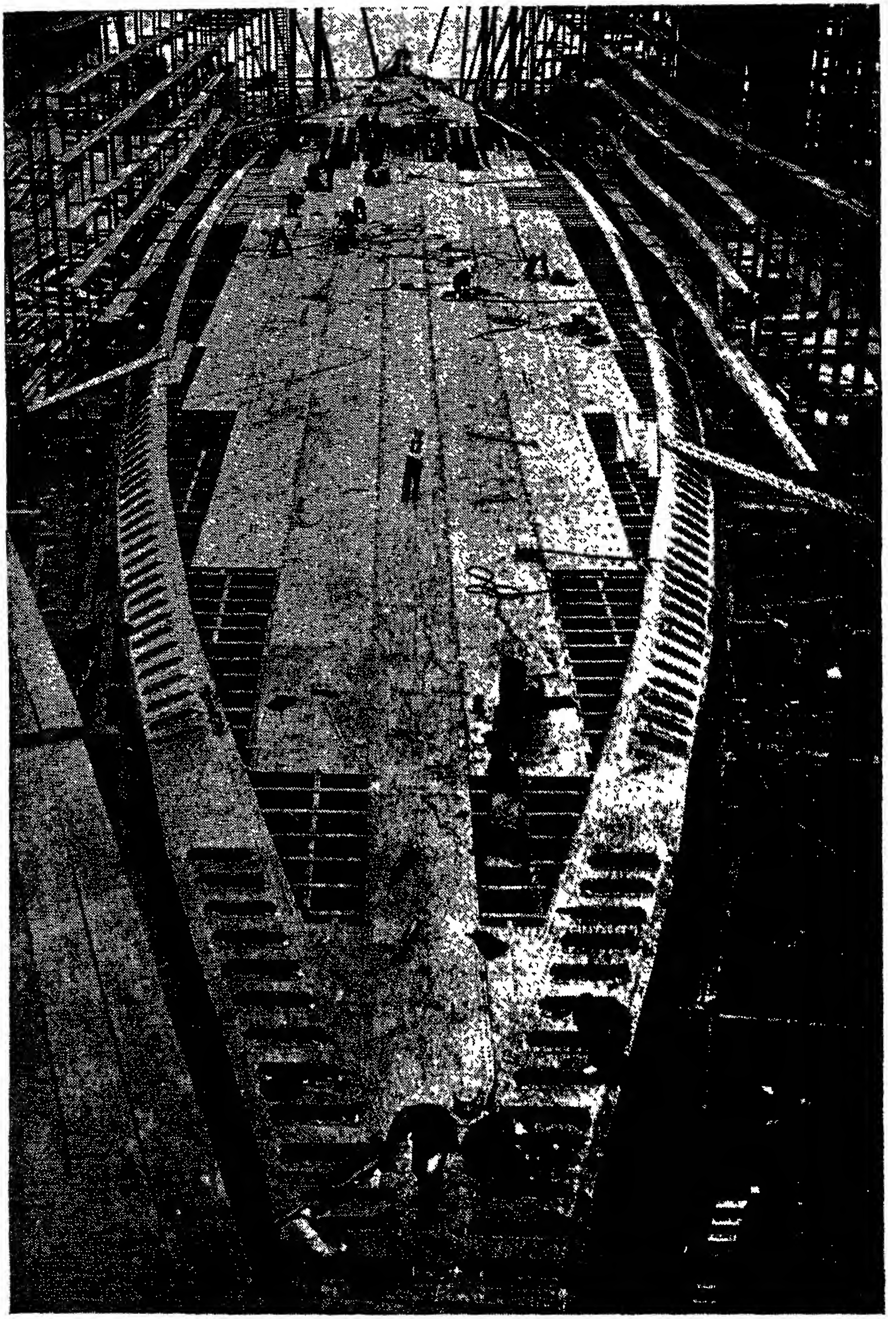


BIRTH OF A SHIP

Shipyards, vitally important to the nation's being, are introduced to us in a striking scene. Early in this ship's construction, the tank top plating is fitted in "strakes" laid fore and aft.

OUR SHIPS AND THOSE WHO BUILD THEM

By W. MUCKLE, M.Sc.

Choosing a site for a shipyard. Many types of craftsmen combine to build Britain's ships. How planning and designing are done—value of scale models. Work in the "mould-loft." The keel is laid. Frame-turning, riveting and welding. How a ship is made watertight. Another vessel goes down the slipway. How launching is done.

We know the ships; we accept their existence with a whole-hearted admiration of the gallant souls who adventure in them to the ends of the earth. But what of those to whom the ships are due? This chapter is devoted to them and the mighty industry they serve so well?

The location of shipyards throughout the country is dependent on several factors. Firstly shipyards must be situated near water so that ships can be easily launched. It is essential, too, that the river on which a shipyard is situated be sufficiently broad to make launching possible. To a large extent the breadth of a river and the launching facilities govern the size of ships which can be built there.

The yard is usually constructed on ground which has a gradual slope down to the river. Rivers with very steep banks are unsuitable for shipbuilding, unless a great amount of money is spent on excavation to prepare a suitable site. A shipyard must also have a considerable water frontage so that fitting out quays can be constructed. Besides the space available for building berths, the shipyard must have sufficient space to accommodate the various shops where the material is prepared before being put on board the ship, as shown in Fig. 1.

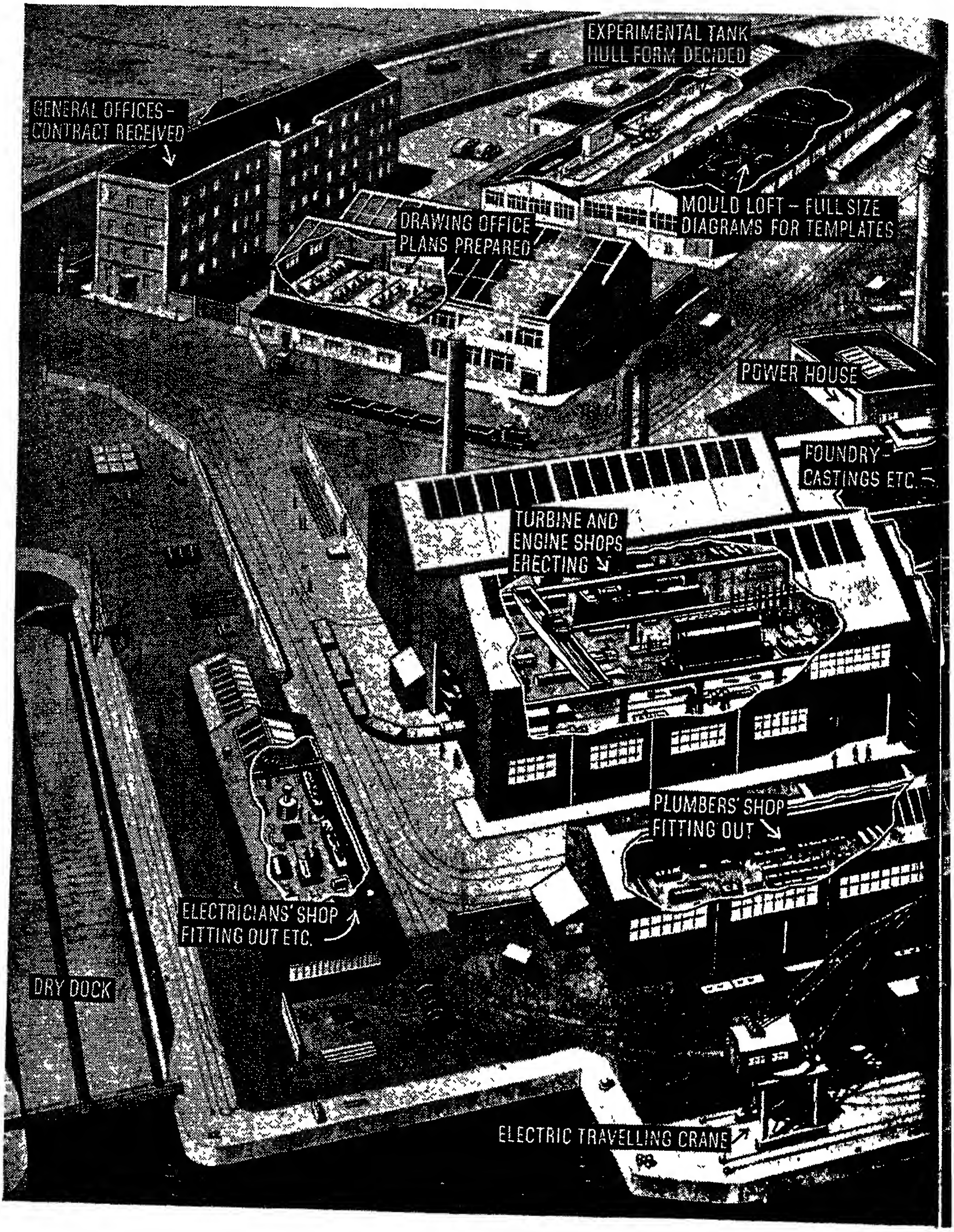
Easy access to raw material is another factor affecting a shipyard's location. A yard should usually be close to a railway, and should be within near reach of a steelworks from which the steel plates and bars for the construction of the ship are obtained. It used to be vitally important that yards should be within easy reach of coal supplies, but nowadays, with the adoption of more electrical machinery in shipyards, the question is not so urgent.

Where ships are made

All this has led to the concentration of shipyards in certain areas of the country where there are good rivers. Two of the most important areas in the British Isles which have been responsible for much of the nation's tonnage are the north-east coast of England and Clydeside. Many of the merchant vessels which have made history have come from these two celebrated districts.

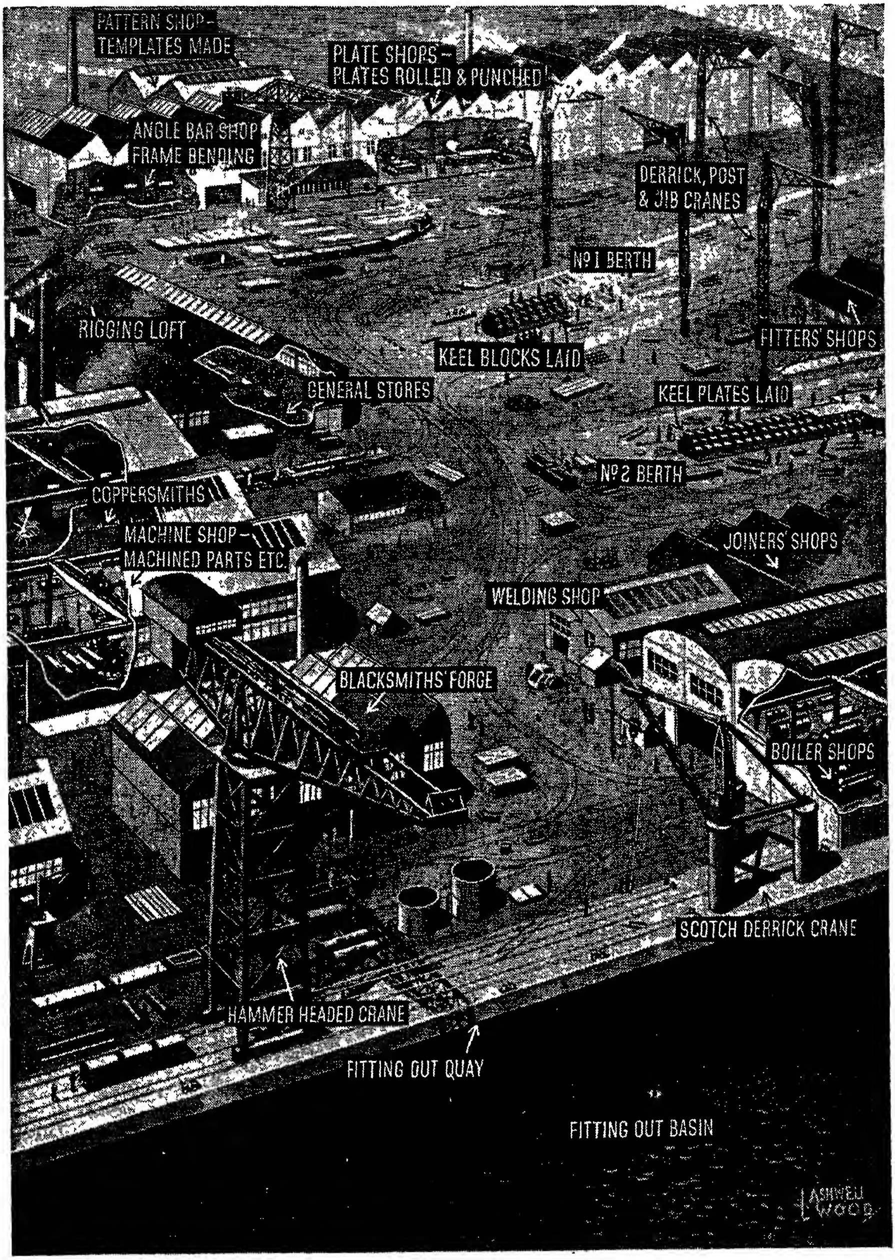
The men employed in the construction of ships are divided into different trades, each with its special duties to perform, and the finished ship is the result of the united efforts of many craftsmen.

One of the most important departments of the shipyard is the "mould-loft" or the "laying-off loft." The loftsmen are responsible for drawing out full-size sections of the vessel and for preparing in wood all the necessary templates from which the various parts of the ship are constructed. The accuracy with which



BIRD'S-EYE VIEW OF A

FIG. 1. *A shipyard is an example of perfect co-operation between many trades. Each of the different departments shown in the above drawing has been carefully planned for maximum efficiency. The keel blocks laid in No. 1 berth mark the first stages in the building of a new vessel.*



BRITISH SHIPYARD LAYOUT

It is essential that the shipyard be situated on a river broad enough to make launching possible, and it is advantageous that the yard should have sufficient water frontage to construct quays for fitting out. Provision must also be made for the different shops involved in the work of construction.

the ship is finally assembled depends to a large extent on the care with which the loftsmen do their work. An error here may mean considerable waste of time.

When the steel is received in the yard in the form of plates and bars, it is only approximately correct in size and shape. The men responsible for cutting the plates and bars to the correct size are known as "platers." They prepare the material according to the working drawings and information supplied by the loft. The plates and bars are cut by them to the true size and shape and have any holes punched, such as rivet holes. The platers are often sub-divided into groups or "squads" which specialize in preparing the material for particular parts of the ship. Thus there are shell-platers who prepare the plates for the outside of the ship or the "shell"; deck-platers, etc.

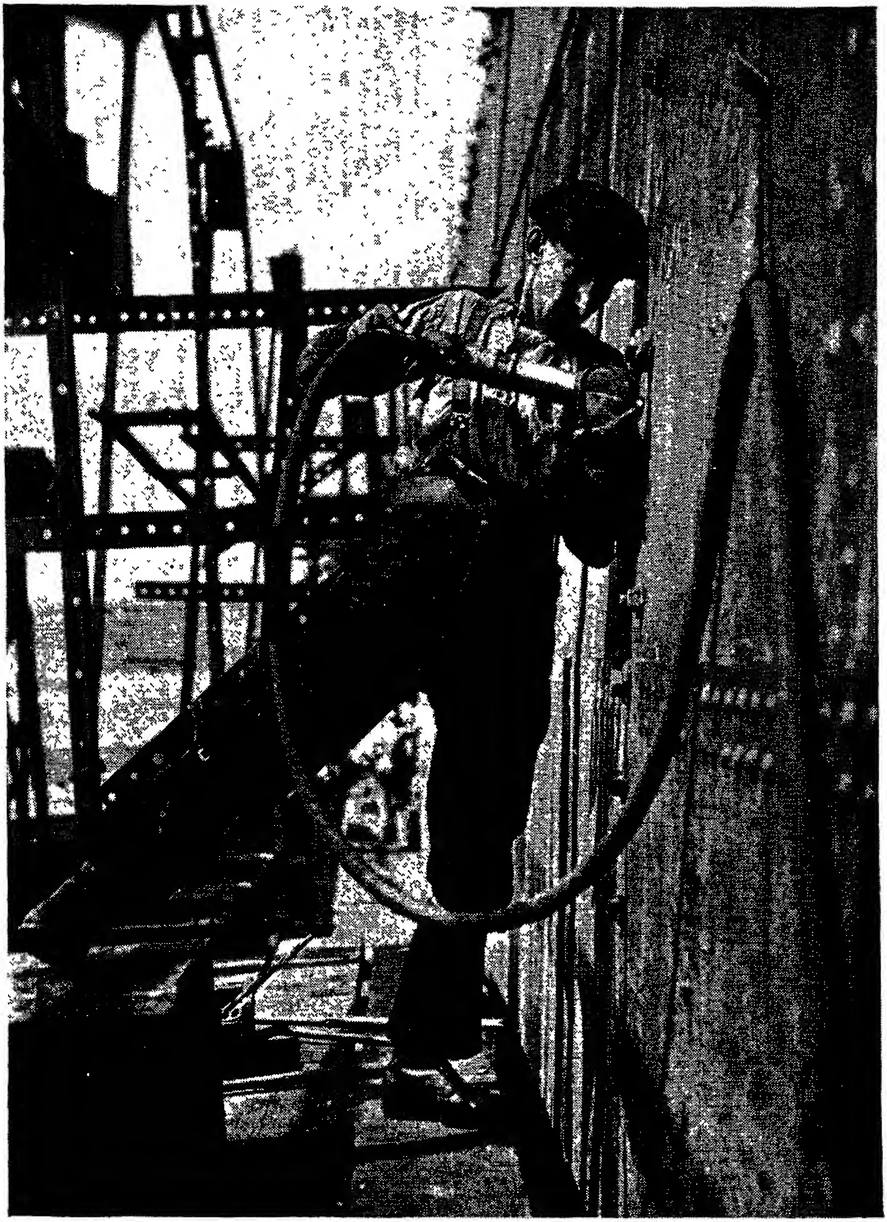
Task of the shipwrights

To the shipwrights is allotted the task of erecting much of the material on the berth. The first job done by them is the laying of the keel and, for this purpose, blocks must be erected and lined-off to the correct slope to the horizontal or "declivity." They also erect and fair up the frames and floors. The floors are vertical plates in the bottom of the vessel varying in depth according to the size of the vessel. Often they are 40-in. or more in depth. These plates extend across the ship and are spaced 24-in. or more apart. At the sides of the vessel, the side-frames are attached to the floors one to each floor. The frames are bars extending from the floors up to the deck, and the shell plating is attached to these frames. The shipwright is responsible for the erection and fairing of these parts so that the plating can easily be fitted on to them. In Fig. 4 are seen the floors and frames of a vessel when erected and faired.

Frame-turners are responsible for bending the side-frames to the correct shape. This job must be done by heating the frame to a red heat in a furnace and then forcing it round a set iron bent to the correct shape and fastened to an iron slab. Fig. 4 shows how this is done. The correct shape of each frame is given to the frame-turners by the loft. The frame is clamped in position while hot and is allowed to cool. In cooling, the frame tends to unbend and the frame-turner must allow for this divergency by giving the frame a little extra curvature.

Old and new methods of riveting

Riveting and welding are the two methods of attaching the various parts of the vessel nowadays. Although the amount of welding employed in shipbuilding is rapidly increasing, and some all-welded ships have been built, a vast amount of riveting is still done. There are three types of riveting—hand, pneumatic and hydraulic. Pneumatic riveting has now largely replaced hand riveting. Hydraulic riveting is used whenever possible in merchant-shipbuilding, but difficulty is often experienced because the jaws of the hydraulic riveter must be able to get round the job (Fig. 3). This type of riveting is therefore limited in its application, but pneumatic riveting can be used in most work (Fig. 2). The rivets are first made red hot in a coke fire, oil or electric oven. Heaters are usually boys, but women are now being employed on this work. The red-hot rivet is then put through the holes in the plates which have to be riveted, and a holder-up keeps the rivet in the hole with a heavy hammer while the pneumatic riveter is applied to the point which is hammered out almost flat. The pneumatic riveter is really a hammer, operated by compressed air, striking the rivet very rapidly. When the rivet has been hammered up to the riveter's satisfaction, he chips off any excess metal so that as smooth a finish as possible is obtained. The efficiency of the



RIVETING A SHIP'S SHELL PLATING

FIG. 2. *Red-hot rivets are placed in the holes and hammered up with the pneumatic riveter. Meantime, to hold the plates in place they have been temporarily bolted to the frames. Some of these bolts, to be removed when riveting is done, can be seen in the illustration. The seaworthiness of a ship may depend on the quality of the riveting and the skill with which it is executed.*

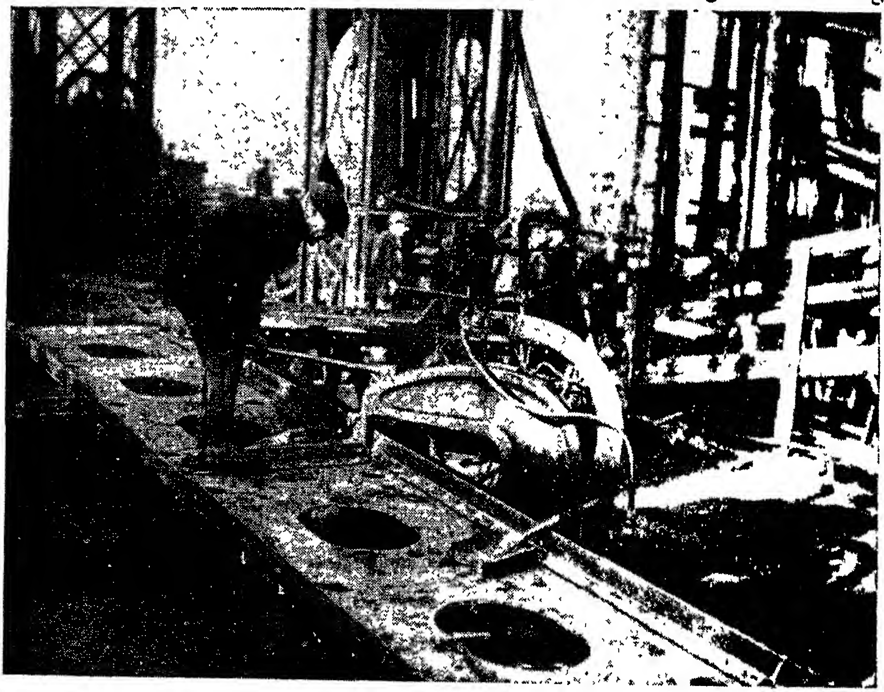
riveting depends upon the accuracy with which the holes have been punched.

Welding is usually now done by means of the electric arc process. The parts to be welded are first brought together and the welder strikes an arc between the job and the electrode, which he carries in a holder. An electric current passes from the generator through the electrode across the arc through the job and back to the generator. The heat generated causes the weld metal to become molten and also raises the parts to be welded to a high temperature in way of the weld. As a result the two parts are fused together into one piece. The welder must protect himself from sparks and from the blue light which comes from the arc. Protection against this is afforded by a semi-transparent shield.

Caulking is necessary on riveted steel work, to make the joints watertight (Fig. 4). Caulking is unnecessary when material has been welded. The caulker who carries out the process usually does the job nowadays with a pneumatic caulker similar to a pneumatic riveter. The edge of the plate to be caulked is first split with a splitting tool. The lower part is then stemmed in, pressing it hard against the other plate, and maintaining watertightness. Along the edge of a caulked seam a distinct groove can be felt.

Blacksmiths aboard ship

Blacksmiths have work to do on board ship. These craftsmen make such things as rails and stanchions, awning stanchions, hinges, cleats for holding the wooden sparring in the holds and gear for battening



GIANT RIVET HAMMER

FIG. 3. *This powerful hydraulic riveter is punching rivets in a part of the hull of a British warship. Although used extensively, this method is not always found practicable because the jaws of the riveting hammer must be able to encircle the job on hand.*

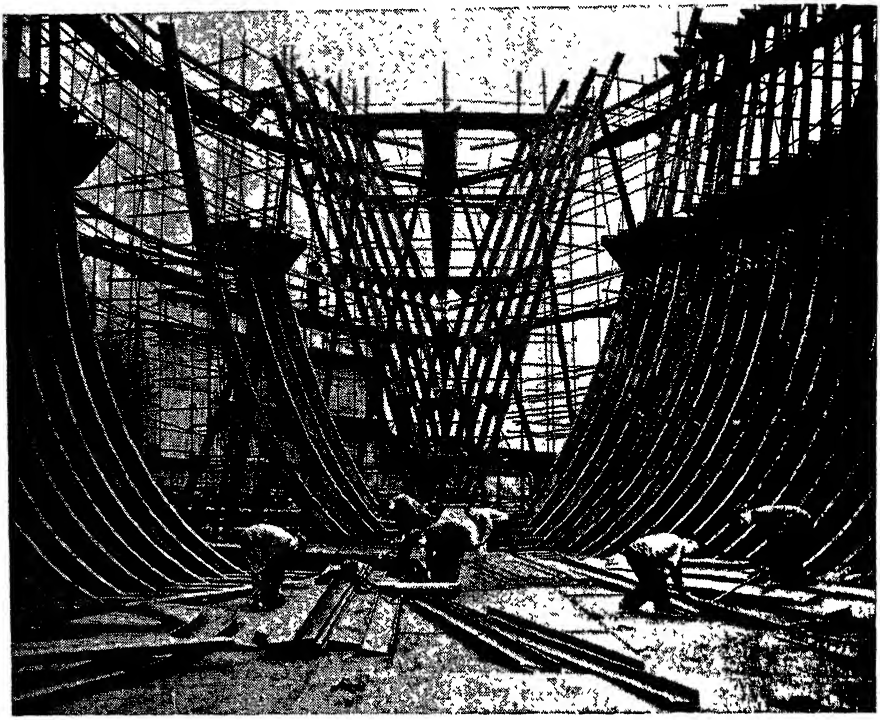
SWUNG INTO PLACE

In the shipyards great masses of steel are swung into position. Here a margin plate (showing the angle bars to which the frame brackets are attached) is being lifted into place on the outside of a vessel—in this case less advanced than the one on page 4.

down hatch covers, and other essentials. Plumbers are responsible for fitting some of the piping. Their work covers the water services to the accommodation, including washing and drinking.

Fitters are employed for fitting piping to ballast tanks, other work by them including fitting of the steering gear, watertight doors, steam piping to winches and windlasses, etc.

Carpenters are responsible for the fitting of much of the woodwork. They make and fit hatch covers and the sparring in the holds which protects the cargo from damage against the frames. They also prepare and lay wood decks which are often fitted over the top of steel decks. On the other hand, joiners do the interior woodwork in cabins and deal with the interior fittings. In an ordinary cargo ship, the joinery represents a small proportion of the work to be done, but in passenger vessels a great deal of it has to be provided.



ERECTING THE MAIN FRAMES

After being bent to the required shape, a ship's frames are slung into position and temporarily bolted in place. They are then raised up and riveted to the rest of the structure. It is in this way that a ship grows, each one of its members having its exact function in the complex structure.

Painters have a great many tasks to perform, from the painting of the outside of the hull—extremely important as preventing corrosion, as well as from the point of view of appearance—to the interior painting and decorating. Often the decorative work is sub-contracted.

Men who design our ships

So far we have mainly considered the men who build the ship and assemble the component parts. Before the construction of a new ship can be started, however, much preliminary work must be done. The layout of the ship must be mapped out on paper and the working drawings prepared for the various parts. All this is done in the offices—the drawing office and the designing office. The designing office is the department which first deals with the ship. The method adopted by the prospective owner is to send out an enquiry to various firms asking for a design which will fulfill certain requirements. The shipyards then prepare designs and quote prices for which they will be prepared to carry out the work. It is essential, therefore, for the shipbuilder to have an expert staff of estimators who can forecast as accurately as possible the cost of building the ship. This price is worked out after the technical requirements of the enquiry have been satisfied and a plan of the vessel drawn out in the designing office.

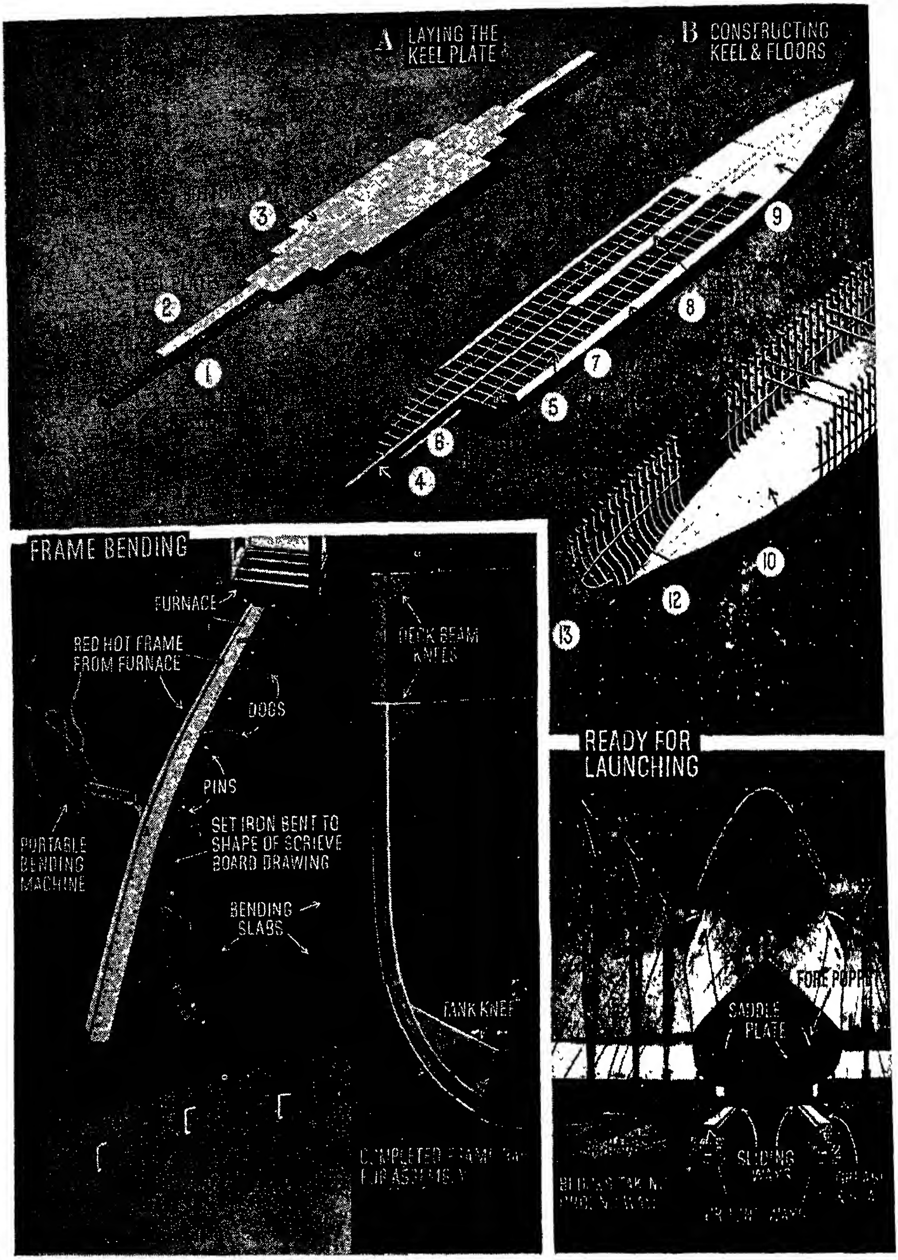
Taking as an example a cargo ship, the

information which the designer requires before starting to build up his design is briefly as follows:—(1) The "deadweight" or load which the ship has to carry—this includes the weights of cargo, fuel (bunkers), stores, and crew and effects; (2) Type of cargo—this often governs the type of ship: e.g., if the vessel is to carry oil in bulk the type of ship will be a tanker which has special features of its own; (3) Type of machinery: i.e., whether steam or oil engines, and whether the boilers have to be coal or oil fired—many variations in type of machinery are now possible and the shipbuilder is often asked to quote for different types; (4) Speed; and (5) The length of voyage which the ship has to be capable of without putting in for refuelling.

The designer's first task is to get out the approximate size of the ship: that is to determine the three principal dimensions, length, breadth, and depth. In doing this he must ensure that the ship is economical to run. In particular, he has to be sure that it is neither too short nor too bluff for the speed required. Usually for fast vessels the length must be increased and the form made finer. Once the dimensions and fullness of the form have been fixed, the total weight or "displacement" of the vessel is determined. The maximum draught of the vessel, that is the amount which the vessel can be immersed measured from the bottom up to the load waterline, is

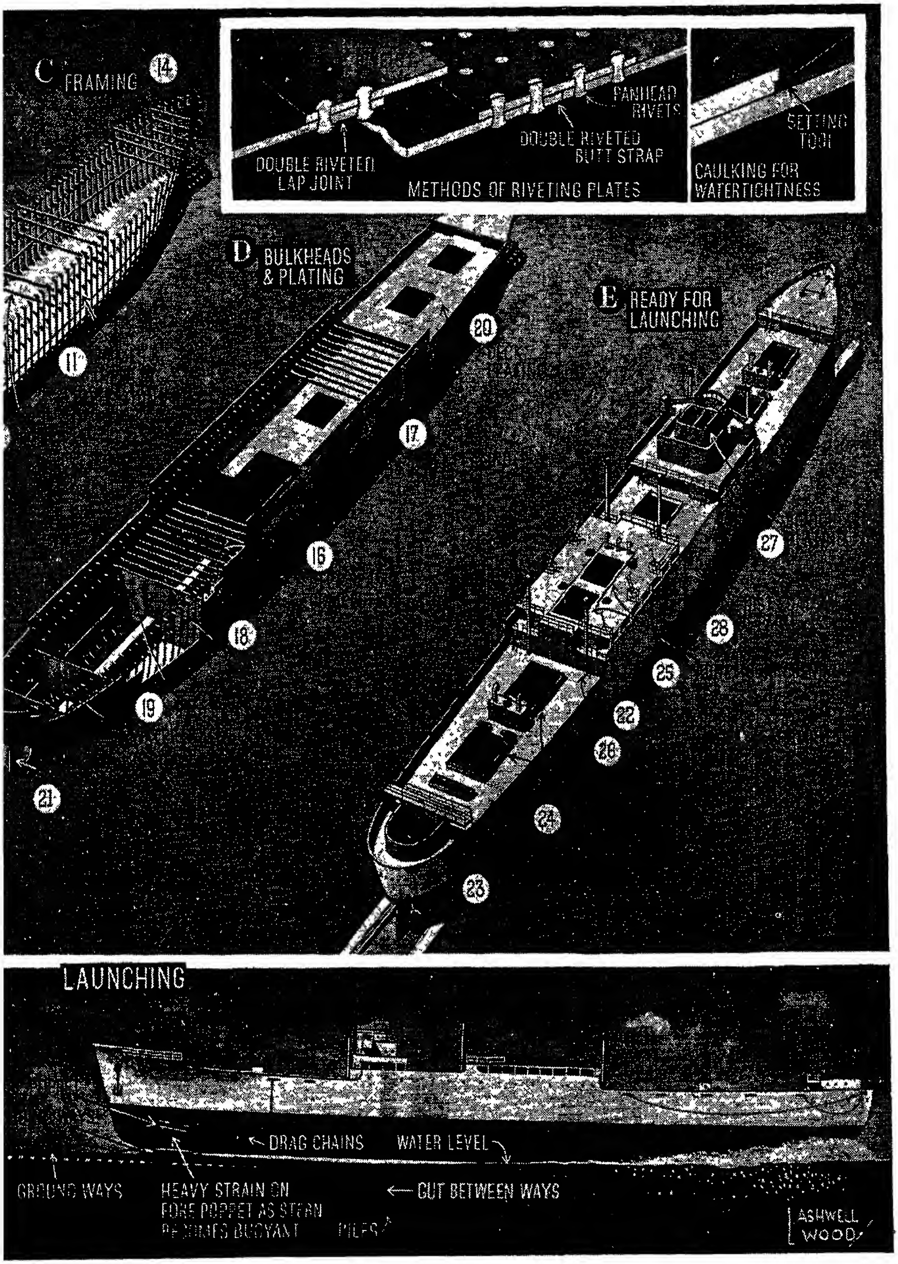
HOW A SHIP'S "SKIN" GROWS

When fitting the shell plating, the inside strakes are put on first and bolted to the frames. Above are seen two lines of plating with a gap between where the outside strake will eventually be fitted. How man is dwarfed by his own productions is well suggested in this low angle shot.



FROM KEEL PLATE TO LAUNCHING:

FIG. 4. *How a ship is built, from laying the keel plate to the moment of launching, is here displayed in a series of stages. Insets show how the frames are bent into shape and assembled; methods of riveting and caulking; and finally the means whereby the slipways function in the launching.*



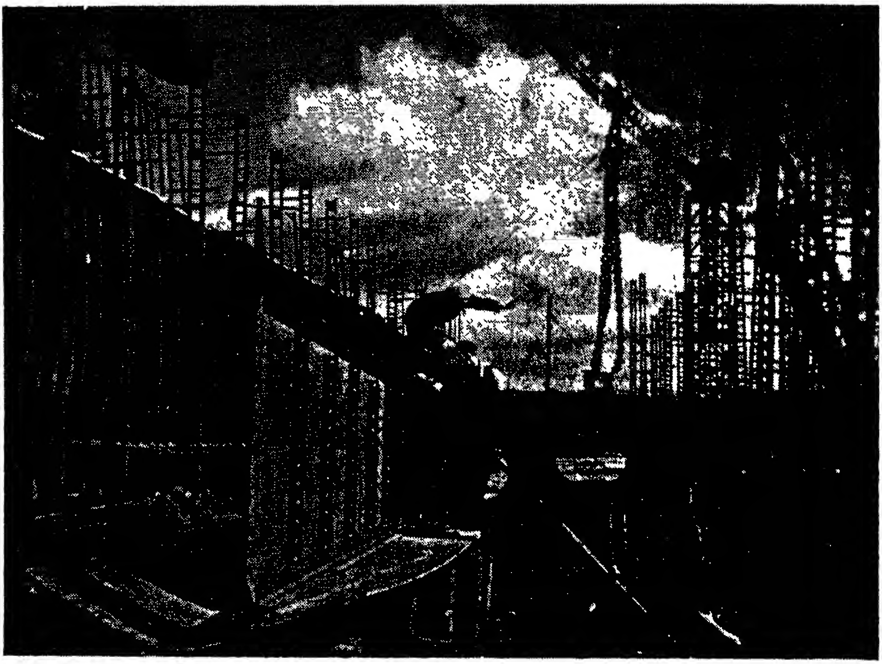
THE GROWTH OF A VESSEL

Thereafter a ship has still to be fitted out and finally tested before beginning her career as a seagoing vessel. What fitting out means is epitomized in Fig. 6 which suggests how much has yet to be done before the ship can be reasonably said to be completed in each of its parts.

now governed by international regulations, involving the "Plimsoll Mark," which is put on the ships at amidships. When at sea in the summer season, the vessel must not be loaded so that the line passing through the centre of the circle is immersed. This maximum draught depends upon the dimensions and form of the vessel.

An important feature in the design of modern vessels is a form requiring as little power as possible to drive it at a given speed. The plan which shows the form of the vessel is known as a "lines plan." This shows a series of sections through the vessel in three different directions—body sections, waterlines and buttocks. All these lines must be fair, smooth curves if the best results are to be obtained in the finished vessel. The plan is usually drawn in the office to a scale of ¼-in. = 1-ft., and when it is finished the form is nearly always tank-tested.

Some firms have their own experimental tanks, but more often forms are tested at the National Tank at Teddington. This is part of the National Physical Laboratory. A wax model of the vessel to be tested is made and the model is towed through water at the appropriate speed. The force necessary to tow the model is measured; that is the resistance of the model. From this resistance it is possible to forecast the resistance of the full-size ship. When all the work is finished, a report is sent back to the shipyard giving any recommended modifications and approximately the power necessary to drive the ship. In addition to this routine work of testing models for shipyards, a great deal of scientific research is carried out.



ERECTING THE FLOORS

A floor plate is being slung into position by means of a crane. It will be temporarily bolted to the centre girder or vertical keel to keep it in position. After a number of floors have been fitted and "faired" they are riveted to the centre keel.

FITTING THE DECK PLATING

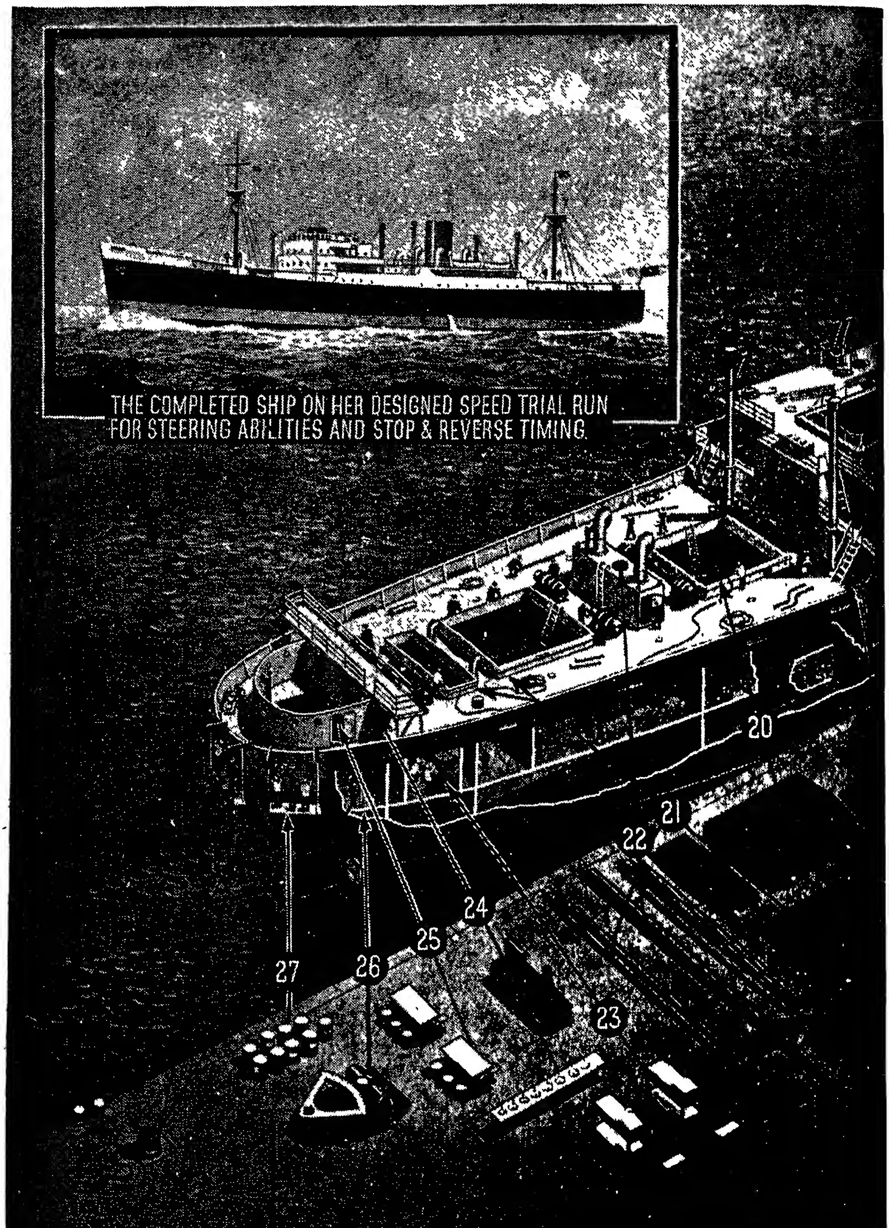
FIG. 5. *Here a deck plate is lowered into place by a derrick. When this has been done it will be bolted to the other plates prior to riveting. The transverse beams which support the plating can be clearly seen in the photograph reproduced above.*

When the form has been decided and the arrangement of the design settled, it is then passed out into the drawing office and particulars of the form are sent to the laying-off loft, where the first job is to "fair up" the lines full-size. This is done by drawing the waterlines on the loft floor. The breadths of the waterlines are drawn full-size, but to save space the lengths are contracted. This job of fairing can be done much more accurately on the full scale than on the small scale.

Preliminary planning

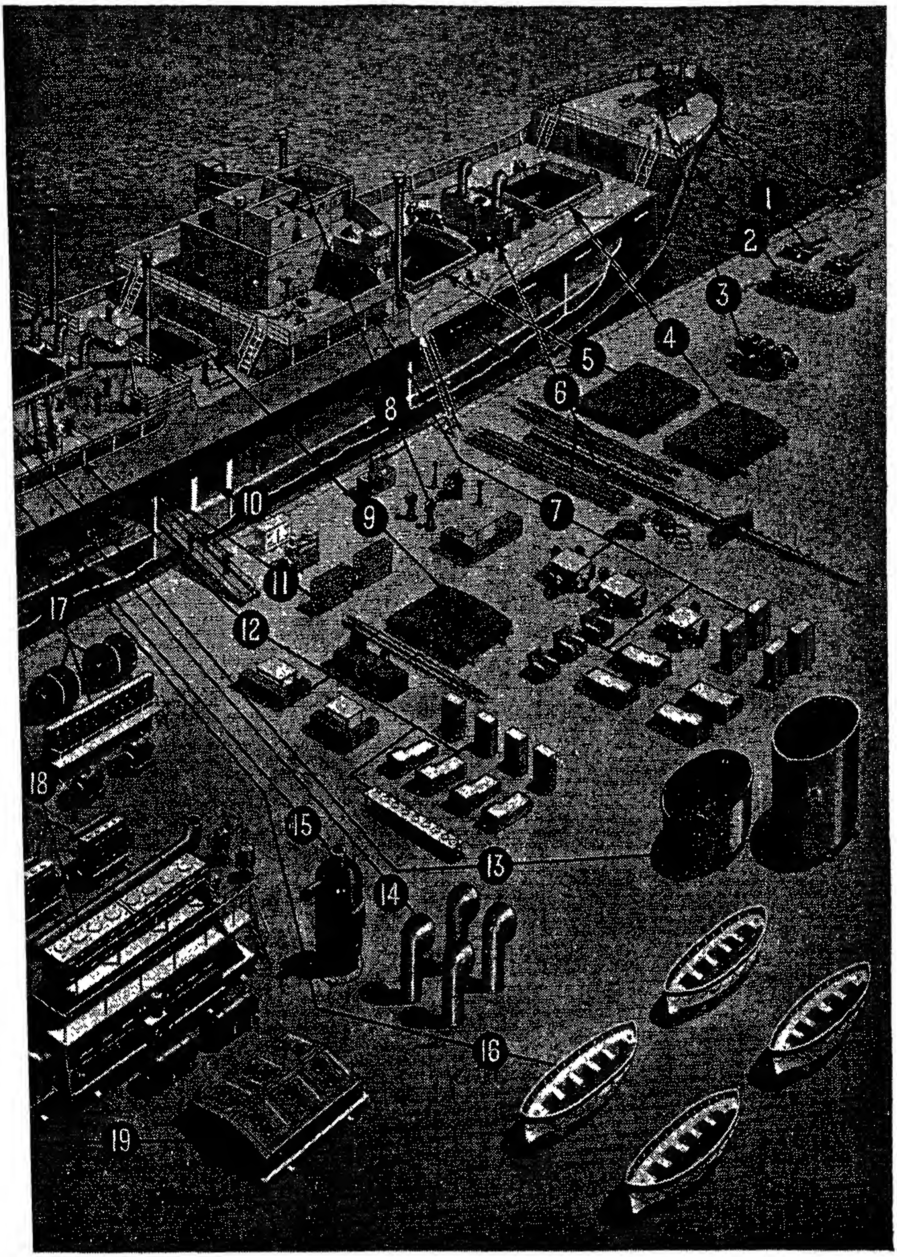
The loftsmen have to adjust the three sets of sections (waterlines, buttocks and body sections) until all correspond with one another and are smooth curves. When these are correct a "scrive board" is prepared in the loft. This is a rectangular wooden board about $\frac{7}{8}$-in. or 1-in. thick, and a little larger than the largest cross section of the ship. The surface of this board is blackened; on it lines are drawn in white chalk and afterwards scrived in with a knife. A transverse section through the ship is drawn full-size at every frame and the positions of all decks and the beam lines for these decks are indicated. The double bottom is shown and the overlaps or seams of the shell plating are painted on. It is from this board that the correct shape of the frames is obtained. The board is made in several pieces so that it is portable and can be carried about. When completed it is usually taken to the framing turning slabs.

While this work is proceeding in the yard, the working drawings are being



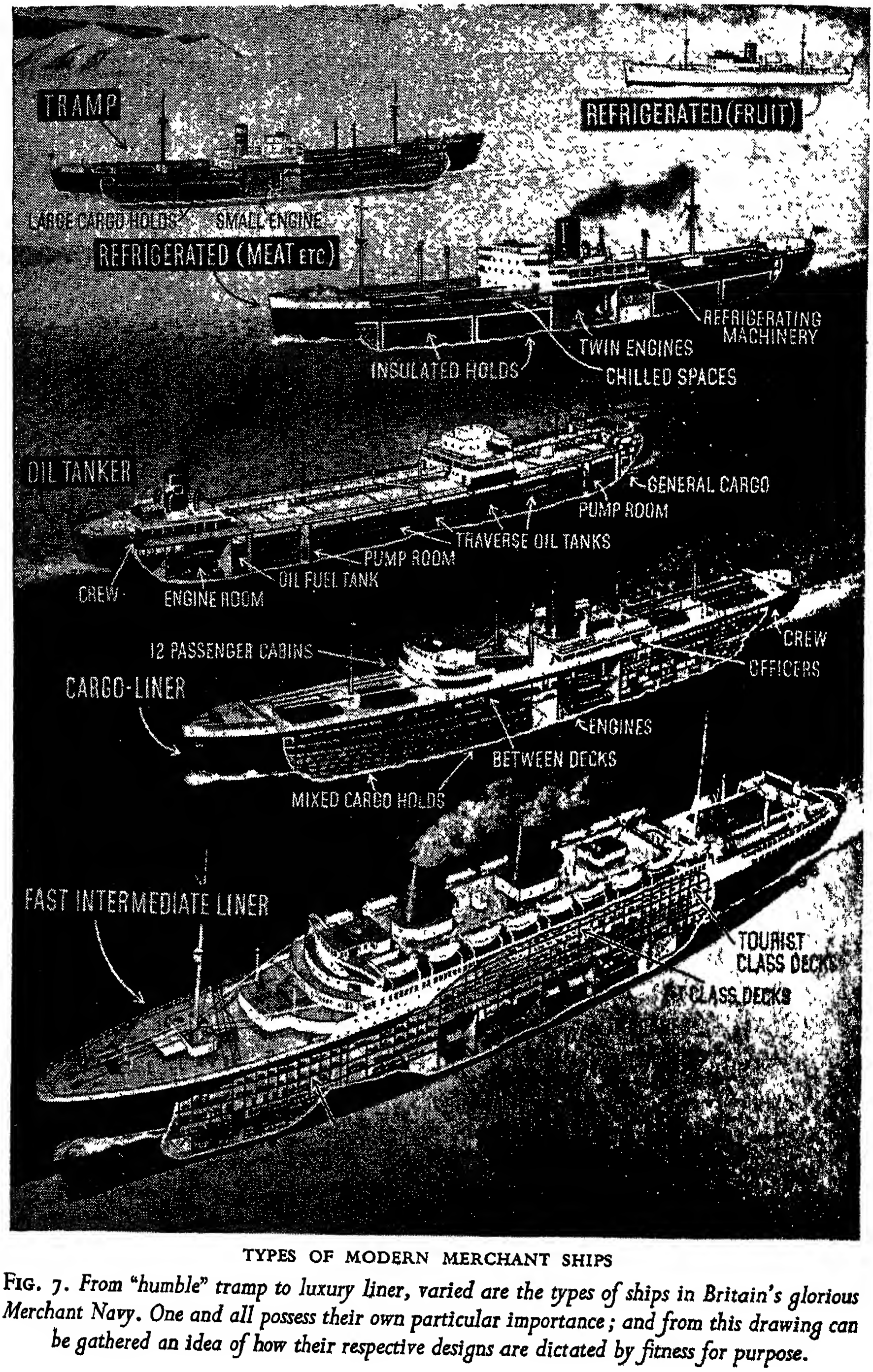
FITTING OUT A

FIG. 6. *How complex is the process of fitting out a ship is here indicated: 1, anchors; 2, anchor cable; 3, anchor windlass; 4, No. 1 hatch cover (here shown assembled); 5, No. 2 hatch cover; 6, foremast and derricks; 7, passengers' equipment; 8, navigation and wireless instruments; 9, No. 3 hatch cover; 10, refrigeration; 11, store bins; 12, galley and washing equipment;*



MODERN CARGO LINER

13, funnel; 14, engine-room ventilators; 15, auxiliary boiler; 16, life-boats; 17, electrical equipment; 18, engine and auxiliary machinery; 19, engine-room skylight; 20, No. 4 hatch cover; 21, No. 5 hatch cover and tonnage hatch; 22, main mast and derricks; 23, crew's equipment; 24, crew's galley; 25, mess equipment; 26, steering gear: 27, final paint is applied.



TYPES OF MODERN MERCHANT SHIPS

FIG. 7. *From "humble" tramp to luxury liner, varied are the types of ships in Britain's glorious Merchant Navy. One and all possess their own particular importance; and from this drawing can be gathered an idea of how their respective designs are dictated by fitness for purpose.*

made in the drawing office. Drawings are prepared for each part of the ship and the material for the construction of the ship is ordered from them. Much of the material is steel in the form of plates and bars; these are brought into the yard and require preparation before being built into the ship. Wood also has to be ordered and brought into the yard before being cut to the correct sizes for building into the ship. When ready, the working drawings are supplied to the various departments of the yard. From these and the information supplied by the loft the men are able to prepare all the material.

How the keel is laid

The first job to be done in commencing actually to build the ship is the laying of the keel—a flat plate running the whole length of the ship, fastening on to the stern-frame at the after end and the stem-bar at the fore end. It is essential that the keel be straight. To ensure this, blocks are first erected on the berth the tops of which are in a perfectly straight line, the line being at a slope to the horizontal known as the declivity. Fig. 4 shows these blocks. The keel plates are laid on top of them and are temporarily bolted together and shored up. When this has been done, the centre keelson or centre girder is fitted in position. This is a vertical line of plates fitting on top of the keel and extending from the outer bottom to the inner bottom or tank top. This is also shored in position. Meanwhile, the floor plates have been cut to the correct sizes having all manholes punched in them and the various connecting angles riveted to them. When ready, the floors are lifted into position and bolted to the centre girder. They are then shored up, faired and levelled. To the ends of the floors is attached a line of plating which is inclined to the horizontal. This line of plating is known as the tank side plate or the tank margin plate.

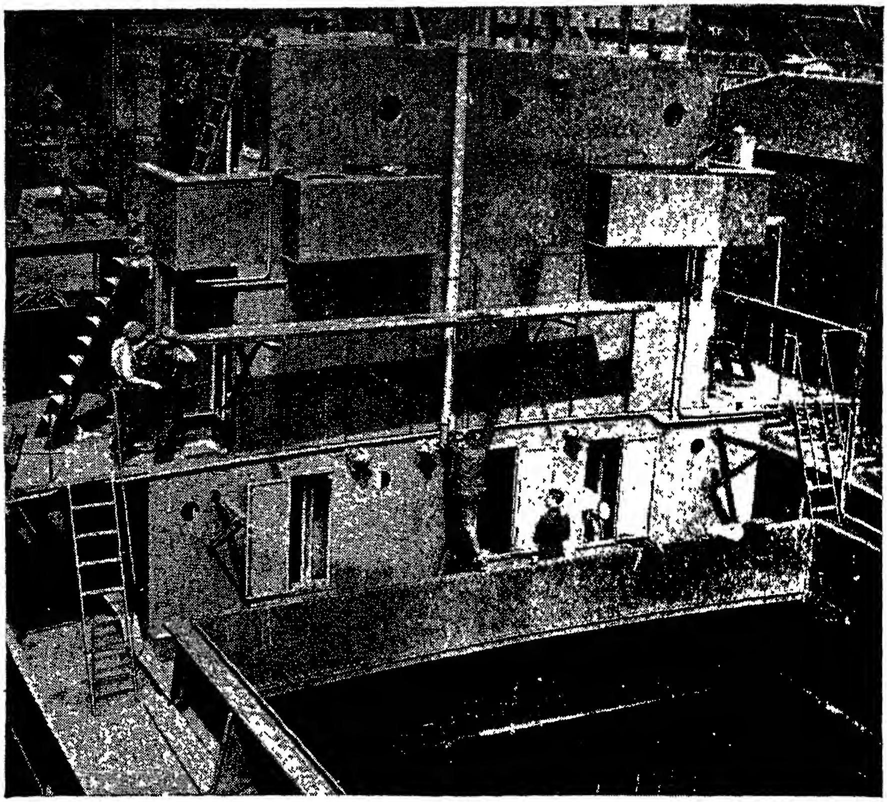
When the tank margin plate is in position, the side frames can be erected. These will have previously been bent to the correct shape, had all necessary holes punched in them, and brackets fitted at their lower ends and at the correct heights to take the deck beams. The frames are hoisted into position and first of all bolted to the tank margin plate. It is essential that the frames be square to the keel and that their outer surface be smooth. At the same time that the frames are being erected it is usual to put the transverse watertight bulkheads in place. These bulkheads run across the ship and divide it into watertight compartments (Fig. 4). The bulkheads are frequently assembled on the ground and lifted into place in one piece. After the framing has been erected the deck beams are fitted and they are faired up in a similar manner to the frames themselves.

Plating the decks

The shell and deck plating can then be proceeded with. These plates may be up to 30-ft. long and 6-ft. or more in width. They are punched and cut to size before being put on board the ship. They are first of all bolted in position and afterwards riveted. Fig. 5 shows men working on the deck plating.

When the shell plating has been put into position it can be riveted up, and afterwards the process of caulking the shell is commenced to make it watertight. To prevent corrosion the shell is then scraped and painted. This completes most of the steelwork of the ship with the exception of such parts as deckhouses, masts, etc.

Prefabrication is a system of construction which is gaining ground. The system is to assemble large parts of the ship's structure altogether clear of the building berth and then lift them into position on the berth. The procedure is more easily applied in welded construction than in



AT WORK ON THE DECKHOUSES

In a vessel approaching completion, work proceeds on the superstructure or deckhouse. Nerve centre of the ship, this contains the navigating bridge, chart room and wheelhouse, where the ship's course is plotted, whence she is steered and orders are signalled to the engine room.

riveted construction. For example, a section of the bottom of a ship may be constructed in this way. The section is built complete with outer and inner bottom plating, floors and tank margin plates. When completed, it is lifted into position on the building blocks and faired into the rest of the structure. A complete fore or after end of a ship may be constructed in this way and the same method can be applied to panels of shell plating and deck plating. To adopt this method, it is essential that the shipyard be properly equipped for the purpose. First, there must be plenty of space clear of the actual building berth, and second, cranes capable of lifting the large weights involved and transferring them to the building berth.

With the ever-increasing application of welding the wider use of the method can be foreseen. On the other hand, a certain amount of prefabrication has always been done in shipbuilding. For example, it is often the practice to build watertight bulkheads completely on the ground before lifting them into position, and the special type of construction of the oil tanker lends itself more easily to this method of construction.

The launch of a vessel is a most important event. The transference of some 2,500 tons of steel, in the case of an

ordinary cargo vessel, from the land into the water in roughly about one minute is something to be wondered at and requires a great deal of organization. Nowadays, the launching of ships is so carefully carried out that hardly, if ever, do accidents occur and giant vessels can be transferred to the water without damage.

Final stages

The carpenters are responsible for a great deal of the preparatory work for a launch. The first thing is to line off the launching ways. Usually two sets of ways are used, one on each side of the ship. These ways consist of lengths of timber varying in breadth with the size of the ship and about 10-in. or 1-ft. thick. Each set of ways consists of a standing way (built upon blocks on the ground, and upon which the ship slides) and a sliding way (which lies on top of the standing way and is fastened to the ship). The standing ways are put in first and given the correct declivity. On them are laid the sliding ways, tallow, soft soap and oil being put in between them. The space between the top of the sliding ways and the ship is filled in with wood packing and the sliding ways are wired to the ship. When the ship moves the sliding ways are carried along with it, and thanks to the lubrication, easily move down the standing ways (Fig. 4).

After the launch, a great deal of work remains to be done on a vessel. One of the principal necessities is the installation of the propelling machinery. Sometimes the ship is towed away to the engine works where the machinery was made, and the engines and boilers hoisted on board and fitted in position (see Fig. 6).

CONDITIONING THE PROPELLER

Above is shown a three-bladed propeller of a multiple-screw ship. The men are engaged in conditioning propeller and plating as a protection against corrosion.

GOING DOWN !

At the top of the shaft the banksman (left) makes sure the miners are not carrying matches or tobacco, checks the working of their lamps, closes the cage gates and signals the winding engineman.

COAL MINING AND MINERS TO-DAY

By GRAHAM R. BAMBER, B.Sc.(Hons.), A.M.I.Mech.E.

Modern mining. Expansion of Britain's second largest industry. Welfare precautions. Visit down a mine. The miner and his job. How coal is won—hand and mechanical methods. The art of shotfiring. Boys in the pits. Coal weighed, screened—and cleaned. "Making a wind." Pithead baths and canteens for our miners.

COAL mining is Britain's second largest industry. Although the industry has to yield place to agriculture in gross value, 80 per cent. of the country's wealth depends on coal. Thus coal mining can be rightly regarded as the mainspring of Britain's industrial supremacy. The Industrial Revolution, which, for all its errors, placed Britain far ahead of other countries in world commerce, was founded upon the steam engine. We remember with pride that the pioneers of the steam engine—Savery, Newcomen, Watt, Trevithick and Stephenson—were British, but we should also remember that the development and adoption of the steam engine were due to the country's abundant reserves of coal.

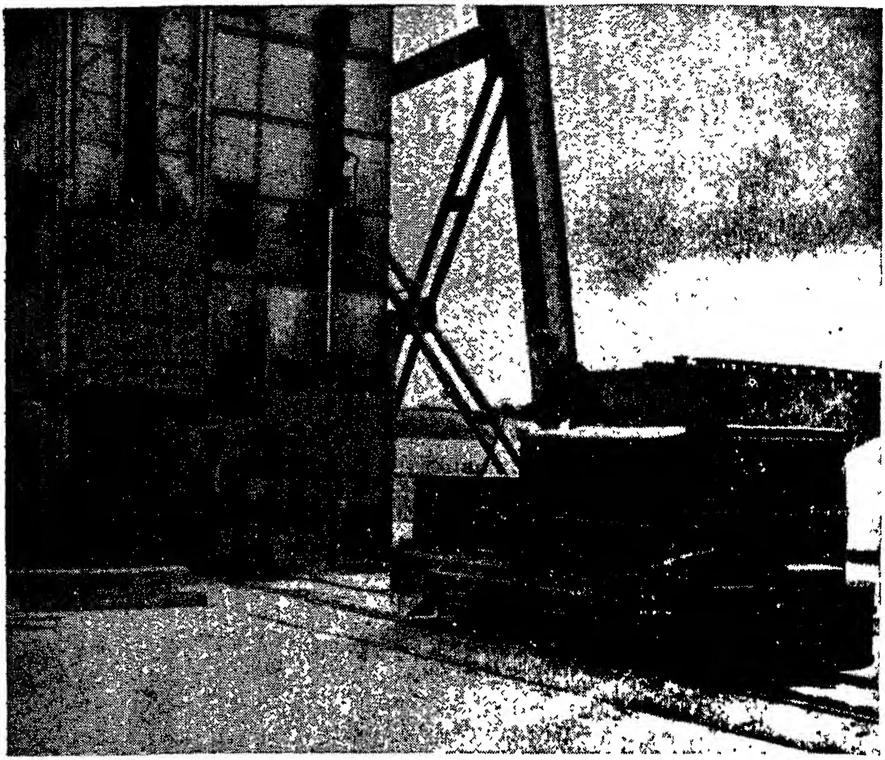
The enormous industrial expansion of the last century naturally reacted upon the coal industry, which steadily increased in size until in 1913 its annual output rose to 287,400,000 tons. The 1914-18 war robbed the British coal industry of much of its prosperity; further blows followed in the disastrous stoppage of 1926 and in the world slump of the early 1930's, but there ensued a steady rise in output. Britain, indeed, is the world's second largest coal producer, yielding place only to that mighty reservoir, the United States of America.

In addition to its function as the source of Britain's power, the coal industry has always made a notable direct contribution to the country's commercial prosperity by means of its export trade. It was the industry's export trade that was the chief sufferer in the reverses of 1914 onwards, but in spite of this Britain remained the world's largest coal exporter.

Seen in perspective

The casualty list from our coal mines is inevitably heavy and is in every sense regrettable, but we must get it into perspective. Roughly speaking, there are as many persons killed and seriously injured on our roads in a month as there are in our collieries in a year. The latest pre-war figures showed that fatalities were approximately 850 per annum and serious injuries about 3,000—or, respectively, 1 and 4 persons per 1,000 employed. Slight injuries were of the order of 130,000 per annum, but it should be remembered that these include all mishaps causing absence for more than three successive days.

Another aspect of the matter on which we need to rid ourselves of some misconceptions is the relative seriousness of different types of accidents. Most of us, nowadays, are alive to the inconsistency of being appalled at a railway accident involving, say, a dozen casualties, and remaining unmoved at the weekly carnage on the roads. There is a similar incon-



UP FOR OVERHAUL

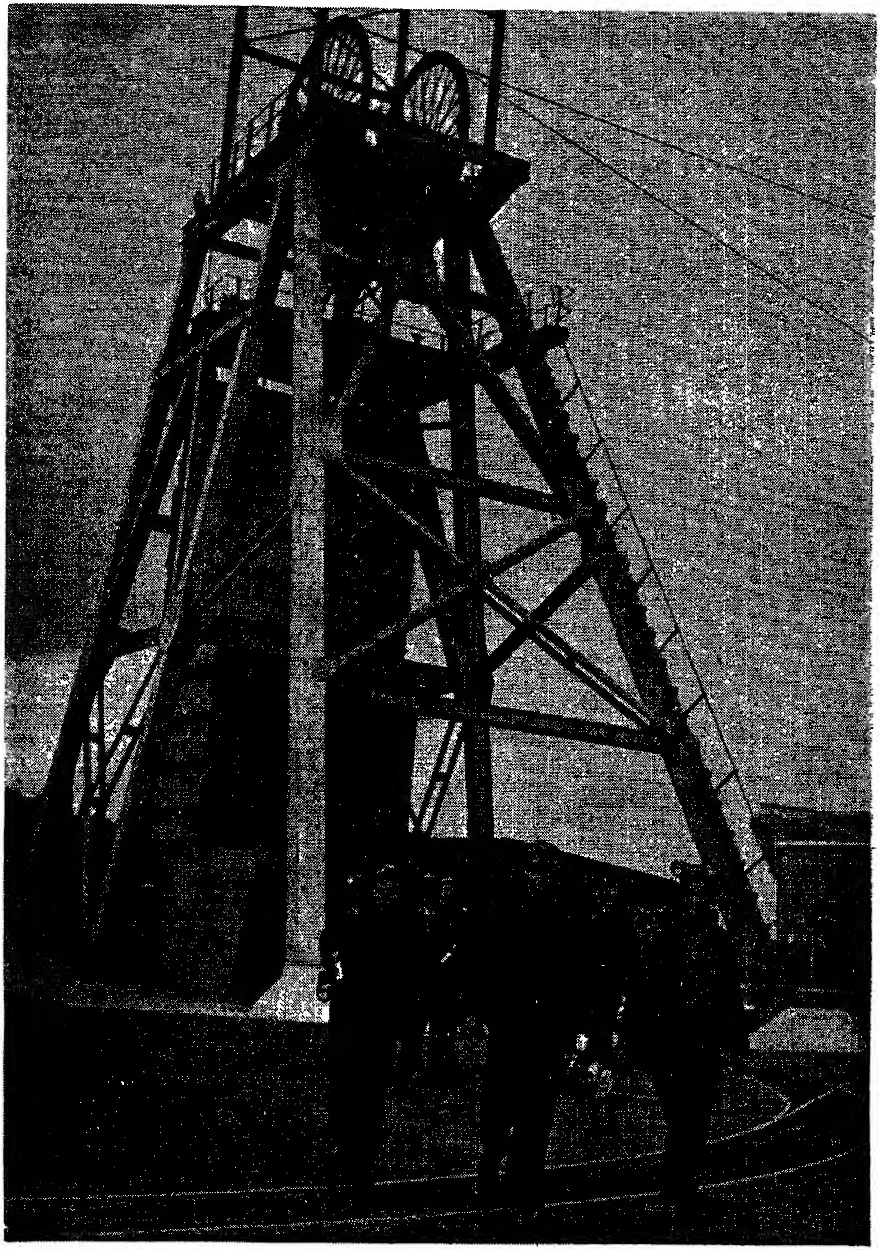
Brought to the surface for one of its periodic overhauls, an underground Diesel engine, specially designed to eliminate fumes that might cause dangerous explosions, is seen emerging from the air lock of the upcast shaft. It is hauled by a surface type of Diesel loco.

sistency in our attitude to mining accidents, and it is traceable to the same cause—that a sensational happening is "news" whereas an everyday one is not. When a colliery explosion occurs every household in the country knows about it, and the more irate members of the public demand that "something should be done about these dreadful disasters."

Explosions rare!

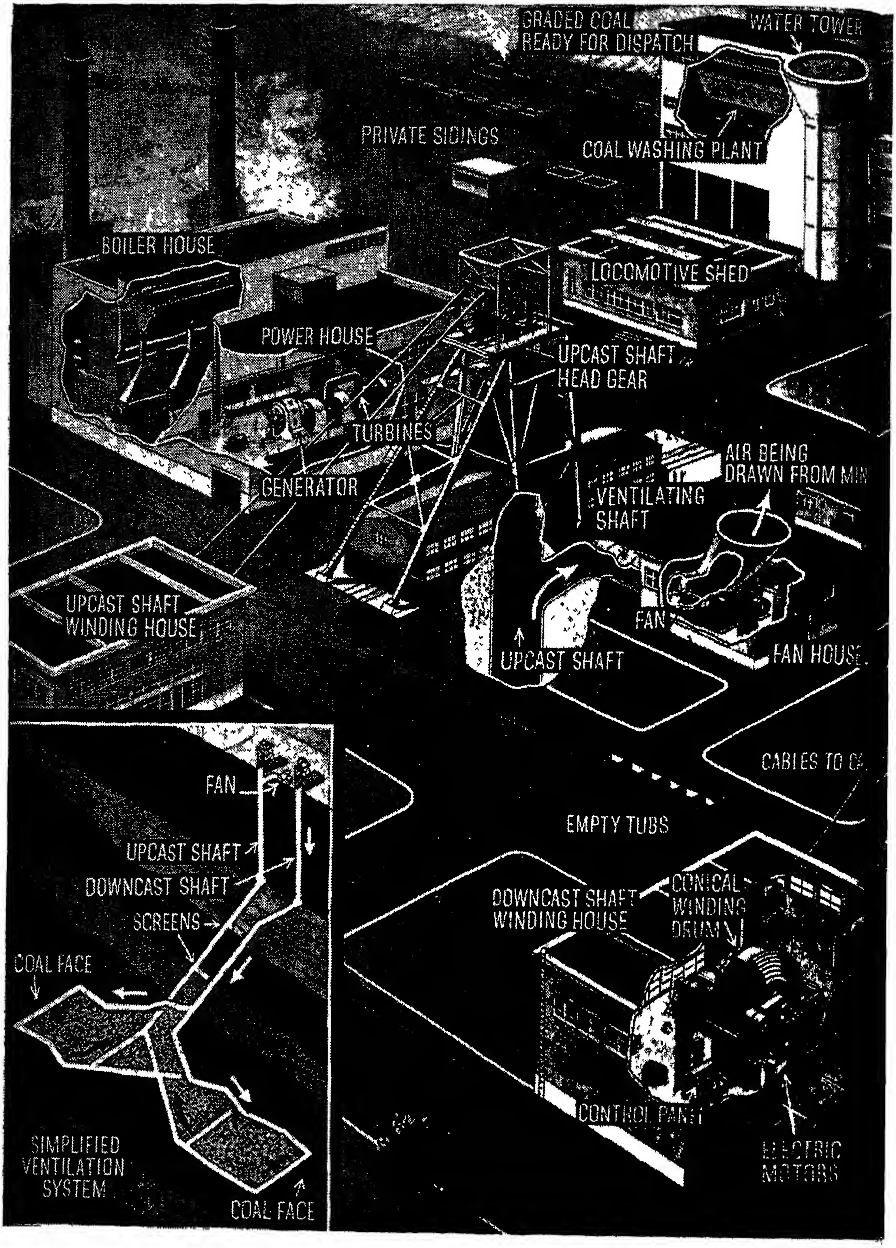
Actually, so many "things have been done" to reduce the hazard that nowadays an explosion is the rare exception, and only about 4 per cent. of mining casualties are due to this cause. By far the most serious type of accident is that arising from falls of ground, which are responsible for no less than half the casualty list. This is not due to any laxity on the part of mining engineers, but results from the inherent difficulty of holding up a depth of, say, half a mile of rock while removing the coal below it. Roof and roadway support is the constant preoccupation of the colliery manager. Each mine is a problem in itself, and any amount of thought and experiment have been devoted to the question; yet the possibility of accident cannot be eliminated.

Next in order of importance are accidents on haulage roads—accidents due to men being caught by the "tubs," or small wagons, in which the coal is brought

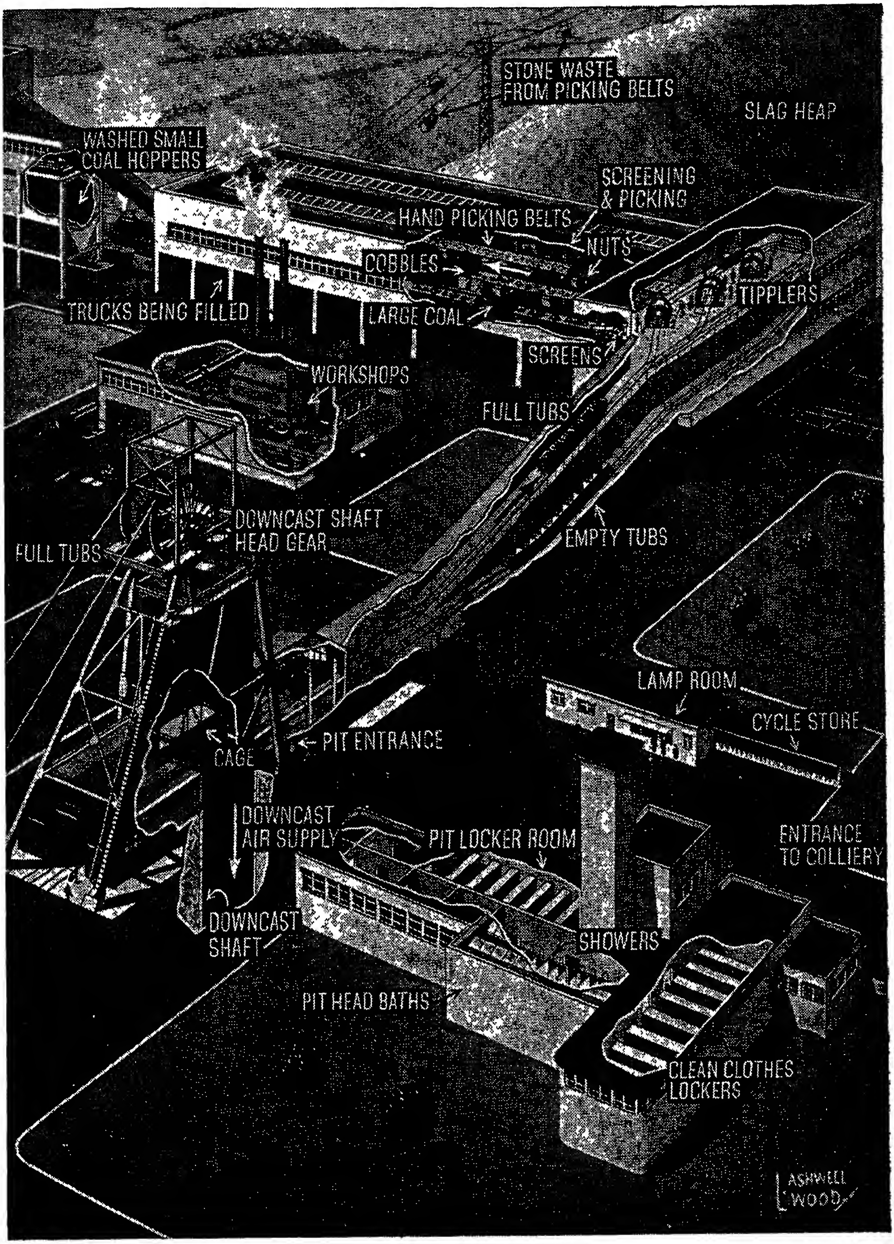


AT THE PITHEAD

At the pithead of one of Britain's most modern mines, some typical miners are seen in the shadow of the great pit headgear. This massively constructed headgear supports the pit cages as they are hauled to the surface and lowered into the depths of the mine. Above we see the returning shift making their way towards bath house, locker room—and home.



ABOVE A COAL MINE:
A modern colliery is planned to ensure the minimum waste of time and labour. The above illustration shows the layout of a typical modern British coal mine. Pithead baths, locker room and lamproom are handily situated within easy access of the pit entrance, while the won coal is brought to the railway wagons, for dispatch in a progressive series of operations. After being



GROUND LEVEL SYSTEM

graded the coal is washed and loaded at the private siding owned by the colliery company. Power and ventilation are two of the most important features of the mine, and above will be seen how steam-powered turbines provide the immense power needed for haulage and the renewal of air in the workings by means of fans, which also extract the used air from the interior of the mine.

out of the pit. Many of these accidents are due to that innate human tendency to take risks, which exists in humanity; but others are due to less preventable causes.

The toll of mining casualties does not spell any indifference on the part of the industry; on the contrary, few industries are more safety-minded than coal mining. One cannot spend long at a colliery without becoming conscious of the all-pervading influence of the Coal Mines Act—an Act passed in 1911 and continuously revised and extended by Regulations until it is now an elaborate safety code for the industry, in which the duties and responsibilities of every official and workman are clearly laid down.

A word must be said about welfare, and about the excellent work of the Miners' Welfare Committee. A tremendous programme of pithead baths, canteens, clinics, educational work and recreational facilities has been prosecuted to the miner's benefit. Many colliery companies have supplemented these provisions by welfare measures of their own.

Trip to a colliery

Now let us take a trip round a modern colliery and meet the mining community at close quarters. On presenting ourselves at the colliery office we somewhat naturally enquire for the manager, but we soon discover that the dignitary with whom we have to make our peace is not the manager but an official known as the agent. Next to the directors, the agent is the ultimate executive authority in the colliery company, and may have control of several or all of the collieries in the group. Indeed, in many cases he is a director himself. Originally the agent was primarily a business official, but the practice is becoming general of appointing as agent a fully qualified mining engineer. Sometimes the agent is also the manager, but more usually there is a separate manager, to whom the agent is superior. The manager is in charge of the running of the entire colliery, both above and below ground, and in him is vested the ultimate statutory responsibility for safety matters under the Coal Mines Act. He must possess a colliery manager's certificate, and is a fully qualified mining engineer—in many cases he has been university-trained.

Meet the manager!

Our interview with the agent has been cordial, and we have been handed over to the manager who will superintend our tour round the colliery. As we cross over to the manager's office he outlines the organization of the underground staff. His immediate junior is the under-manager, who supervises all work underground and is also required to have statutory qualifications. The workings are divided into a number of districts, each of which is in charge of an overman, who must hold an appropriate certificate, and is roughly equivalent to the foreman in a factory department. Beneath the overmen are deputy-overmen, commonly known as deputies, corresponding to factory charge hands. The deputy, however, has a number of specific responsibilities for ensuring the safety of his district, particularly with regard to gas and support of the roof, and has special powers to act in the event of any occurrence likely to cause danger.

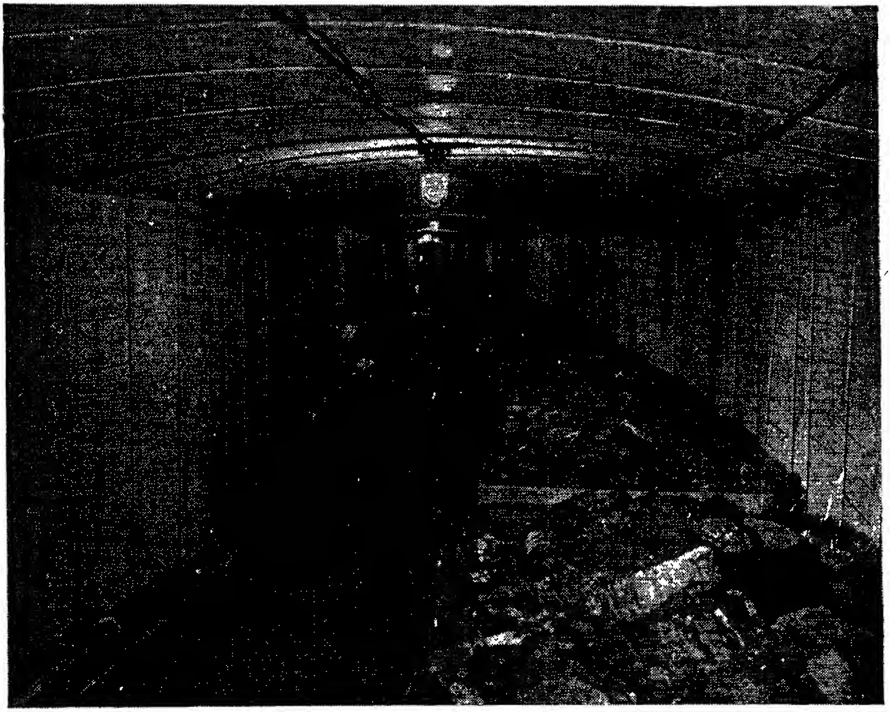
While explaining these matters, the manager is fitting us out with an old mackintosh and a miner's safety helmet; fortunately we have had the good sense to wear our oldest clothes and our heaviest boots. Our helmet is made of some moulded composition, and is so light that we venture doubts about its strength. For answer, the manager fishes out a helmet, the crown of which has been cracked. We view it apprehensively. "The man who was wearing this helmet," he says, "had a hundredweight

of rock fall on his head. He was knocked silly and had his head cut, but he is back in the pit now, absolutely none the worse."

The manager takes us across to the baths to see the first stage of the proceedings. The afternoon shift is preparing to go down. We peep into a cheerful looking canteen where some of the men are indulging in a snack, and pass into the baths, at the door of which we are met by a glorious warmth. We enter a locker room where each man strips and hangs up his clean clothes in his own private locker, where they will be dried by a current of warm air. He then takes his towel and passes forward to a second locker room where his pit clothes are kept and which are now beautifully warm and dry. On coming out of the pit at the end of his shift he will leave his pit clothes in this second locker room and walk across to the bath-house, which is through an archway alongside, where he can indulge in a hot shower; thence he will pass to the clean-clothes locker room and, after a visit to the canteen if he so wishes, will depart home clean, warm, dry and fed. Fig. 6 gives an idea of the facilities afforded.

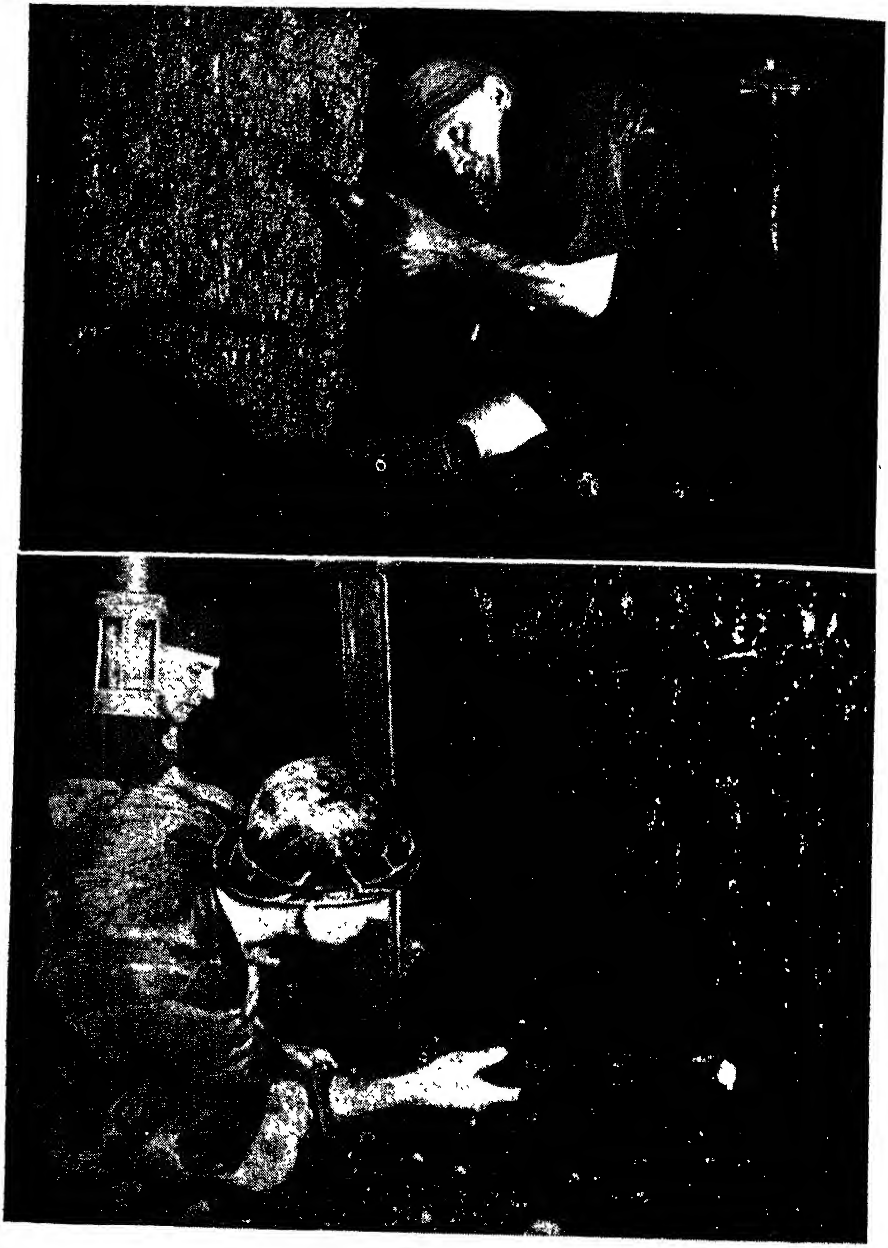
Safety lamps are lit

The manager takes us inside the lamp-room, where the floor is occupied by racks upon racks of lamp accumulators being charged. The lampman provides lamps for the manager and ourselves. Our lamp looks rather like a metal light-house about a foot high, with a loose carrying hook at the top, and weighs about 7 lb. A twist of the lantern section



HAULAGE ROAD IN A MODERN MINE

Nearly a mile underground, a checker is busily dealing with coal-loaded trucks as they pass on their way to the surface. Here is seen how mines are improved by modern tunnelling methods.

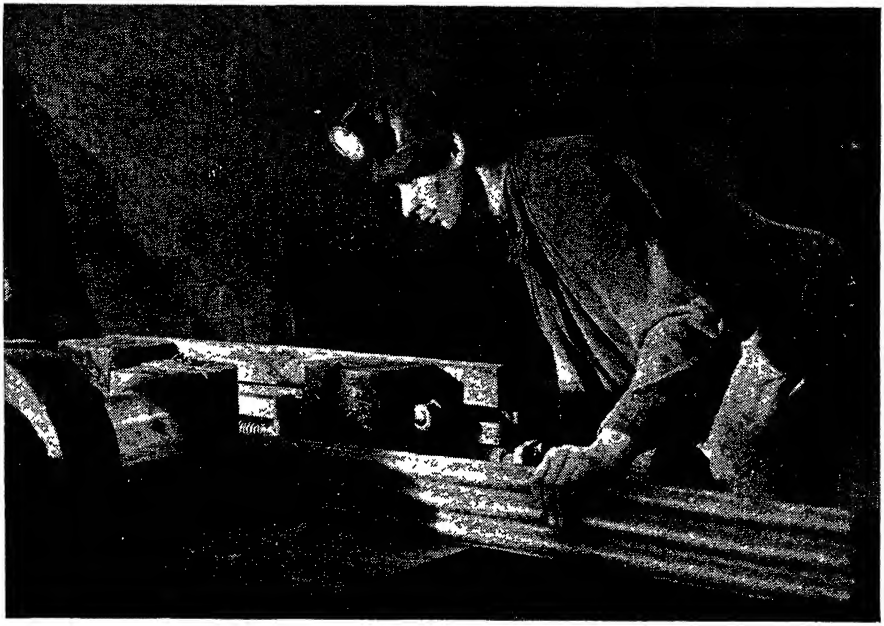


MINERS AT WORK

Here, in the depths of a coal mine, brawny miners are skilfully, tirelessly plying their craft. What sort of pick is used, whether pneumatic or the old hand-wielded kind, is dictated by local conditions. (Top) winning coal with a pneumatic pick, in some seams the most suitable way. (Bottom) in a thin seam, a helmeted miner is seen "hand getting" the coal from the coal face.

switches on the light. It is impossible for us to open the lamp, but the lampman has a magnetic unlocking device by which the upper lantern section can be removed and the accumulator taken out for recharging. A major portion of his time is occupied by inspecting and repairing accumulators, replenishing electrolyte, recharging and suchlike duties.

Remembering our past troubles with flashlamps we ask what happens to the miner if his lamp becomes deranged. For answer, the manager lights a lamp and throws it on to the cement floor, from which he picks it up still alight and absolutely undamaged. "I have even known of a lamp falling down a shaft and remaining alight," he says. We see, too, another type of lamp—the cap lamp. This is fixed to the helmet, and a flexible cable leads down to the battery case, which is carried on the belt. This type leaves both hands free, and the light is directed wherever the miner turns his head. We are also shown some oil lamps, which are required in a certain proportion for gas testing. The flame is turned very low, and if firedamp be present it burns above the tiny speck of flame in a faint blue cone—signalling danger.



IN A MODERN MINE

This mine worker is seen straightening a steel roof strap in a hydraulic press. This process enables roof straps, that have bent under the enormous pressure they have sometimes to withstand, to be renewed for further use. Steel thus represents a considerable economy over timber.

We now leave our matches and smoking materials and go out into the yard and up a flight of steps to the heapstead. "Rather curious," we remark, "to be going upstairs for a trip underground." The manager smiles and explains that this is to allow the tubs of coal to run by gravity to the screening plant. He tugs at a door leading to a small passage. As the door closes behind us, a curious plucking in our eardrums announces a change in air pressure, which is repeated when the manager

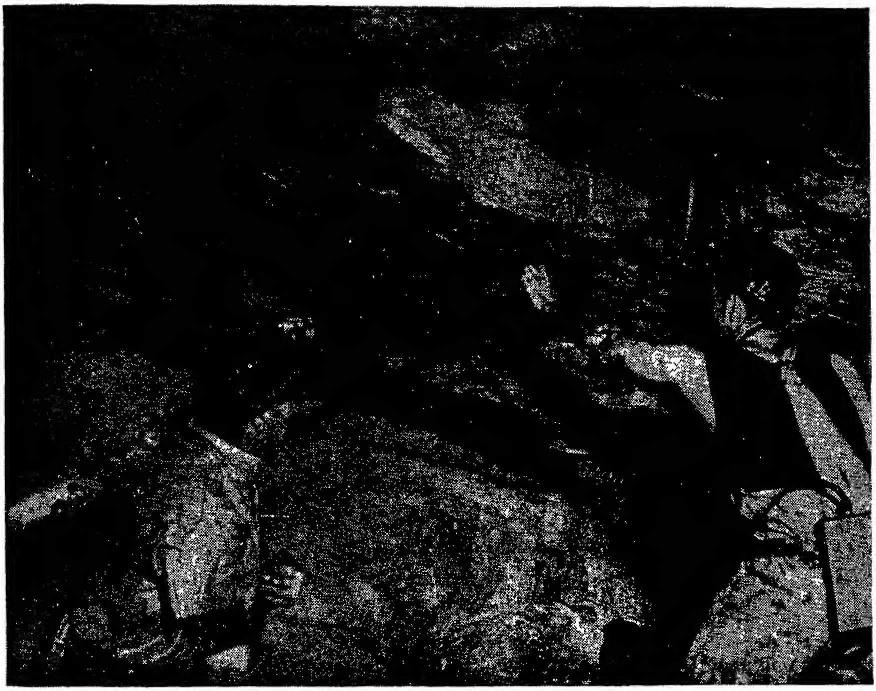
pulls open a second door in front of us. "We are passing through the air lock," says the manager. "There are two shafts, and the pit is ventilated by sucking the foul air out through this shaft, called the upcast, by means of a powerful fan, and letting fresh air make its way down the other shaft, which is open and is called the downcast. The whole of the workings are planned so that a proper ventilating circuit is maintained throughout."

At the pit mouth

We are now standing at the pit mouth, protected on each side by two sets of gates, one for each of the two cages; with 2ft. gauge rails leading to and from each set of gates provide for empty tubs to be wheeled into the cage and full tubs wheeled out. The cages counterbalance each other, one ascending while the other descends (Fig. 4). In due course the banksman signals three rings to the engineman to notify that he will be winding men, feels us over to make sure that we have no matches, examines our lamps, and ushers us into the cage. Built of perforated steel plate on a steel framework, it is wet and slimy with coal dust; and we pick our way over a tub catch and between tub rails. The banksman fixes gates on to the cage and rings us away. Nothing happens until the onsetter at the pit bottom confirms the signal; then the cage sways slightly, hovers uncertainly for a moment, and dives giddily into the blackness. The sensation is curious; our eardrums are plucking; we find ourselves swallowing and clutching the gritty handrail. We can see absolutely nothing but

DEEP IN A COAL MINE

Beneath the ponderous roof of the mine fillers are at work. Armed with pointed shovels, they load the loose coal from sections of the face on to the conveyor. As the face is cleared the fillers set a new line of props to support the freshly-exposed section of the face.



ADVANCING A ROADWAY

FIG. 1. *Drilling a shot hole for "roof ripping." The hole will be charged with explosive cartridges by the shotfirer and the roof cleared to open out the roadway to its full height. The explosives used in such operations are all of special types to avoid the danger of igniting gas.*

the glow of our safety lamps in the cage.

After what seems an age the motion becomes easier, and we are able to listen more contentedly to the swish of the cage as it races downwards. "We are doing about 40 m.p.h. now," says the manager casually. "When we are coal drawing, the cages do over 50." Then the cage seems to rise, and we could swear that we were flying up, up, up again to the surface. Actually we are slowing down, and in the darkness the effect is similar to that experienced when a railway train slows in a tunnel giving us the impression that it is running backwards. The motion slackens; reduces to a crawl; lights spring up below our feet and rise up to meet us; the cage drops gently on to a solid support, and the onsetter opens the gate.

The pit bottom is a spacious, vaulted, brick-built chamber, scrupulously whitewashed and liberally lit by electric light. On the rails in front of us as we leave the cage are lines of tubs, full of coal, waiting to be sent to the surface.

Journey by paddy mail

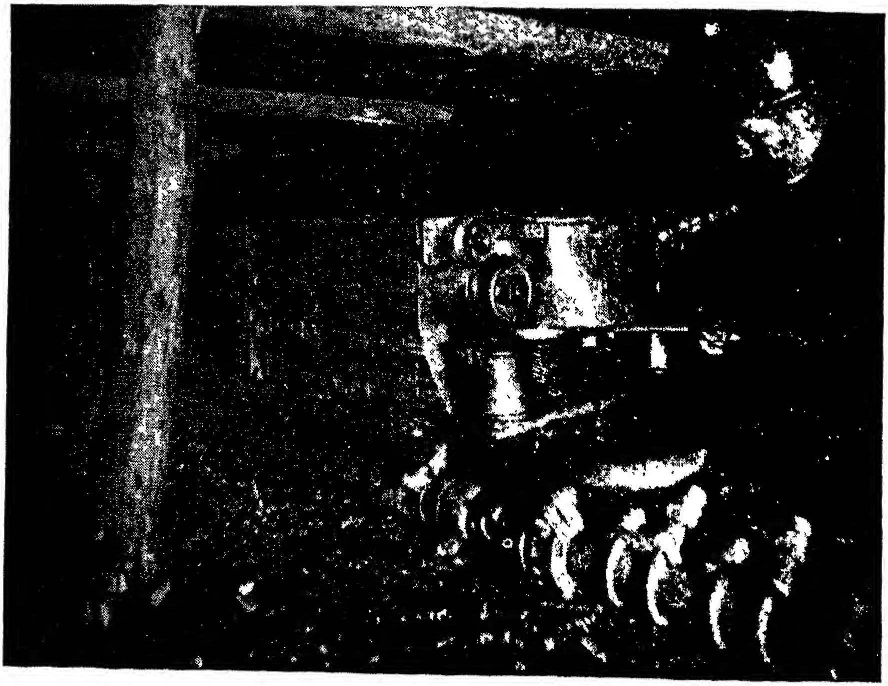
Behind the cages the rails continue, to receive empty tubs brought down by the cages and run them to the workings. We make our way past the lines of tubs, take a turning at a road junction, and arrive at another road where a paddy mail awaits us. It is a train composed of trucks fitted with seats, and is pulled along by a haulage rope running between the rails and driven by an electric haulage engine in a chamber at our rear. We take our

seats, the train attendant climbs up in front, and signals to the engineman by pressing a metal rake on to a pair of signal wires running along the side of this underground roadway.

The train moves away. Quickly we leave the electric lights behind, but the road in front of us is brilliantly lit by a headlamp on the train. We are running at about 8 m.p.h., but the confinement of the roadway gives us an impression of greater speed. The road is good, and is built of steel arches backed by wooden shuttering and stone packing. The manager tells us that the run is just over a mile. "Most man-haulages," he says, "are on the endless-rope system like this one. There is another train coming outbye as this one goes inbye—something like the two cages in a shaft—and we shall pass it halfway. Some paddy mails are run by electric battery locomotives, and there are one or two in the country run by Diesel locomotives which are specially built to eliminate fumes and to avoid risk of firedamp explosion."

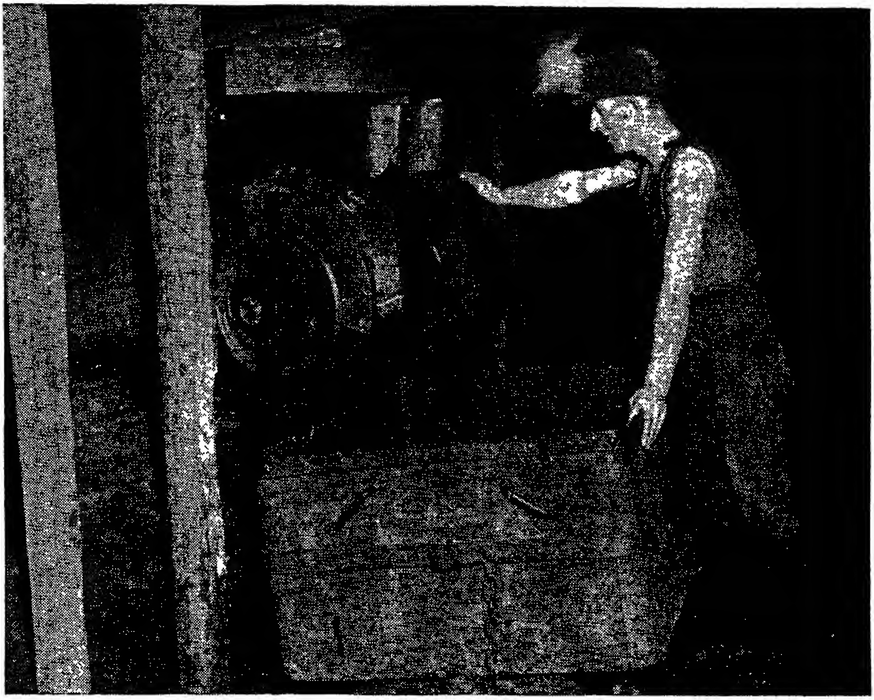
How coal is mined

While travelling we take the opportunity to ask the manager how coal is mined? "It is mined in all sorts of ways," he replies. "No two collieries are ever exactly alike; each presents its own problems according to the thickness, inclination, and nature of the seam, depth from the surface, amount the rocks are disturbed, type of roof and floor, proximity of other workings, and so on. But broadly speaking there are two methods. The most general, and the one you will



COALCUTTER IN ACTION

FIG. 2. *At the controls of a cutter driven by compressed air, the worker has the coal face on his right. The powerful machine is steadily cutting a slot under the coal so that it can more easily be broken down. A strong wire rope extends from a drum in the machine to an anchoring prop.*



FACE CONVEYOR

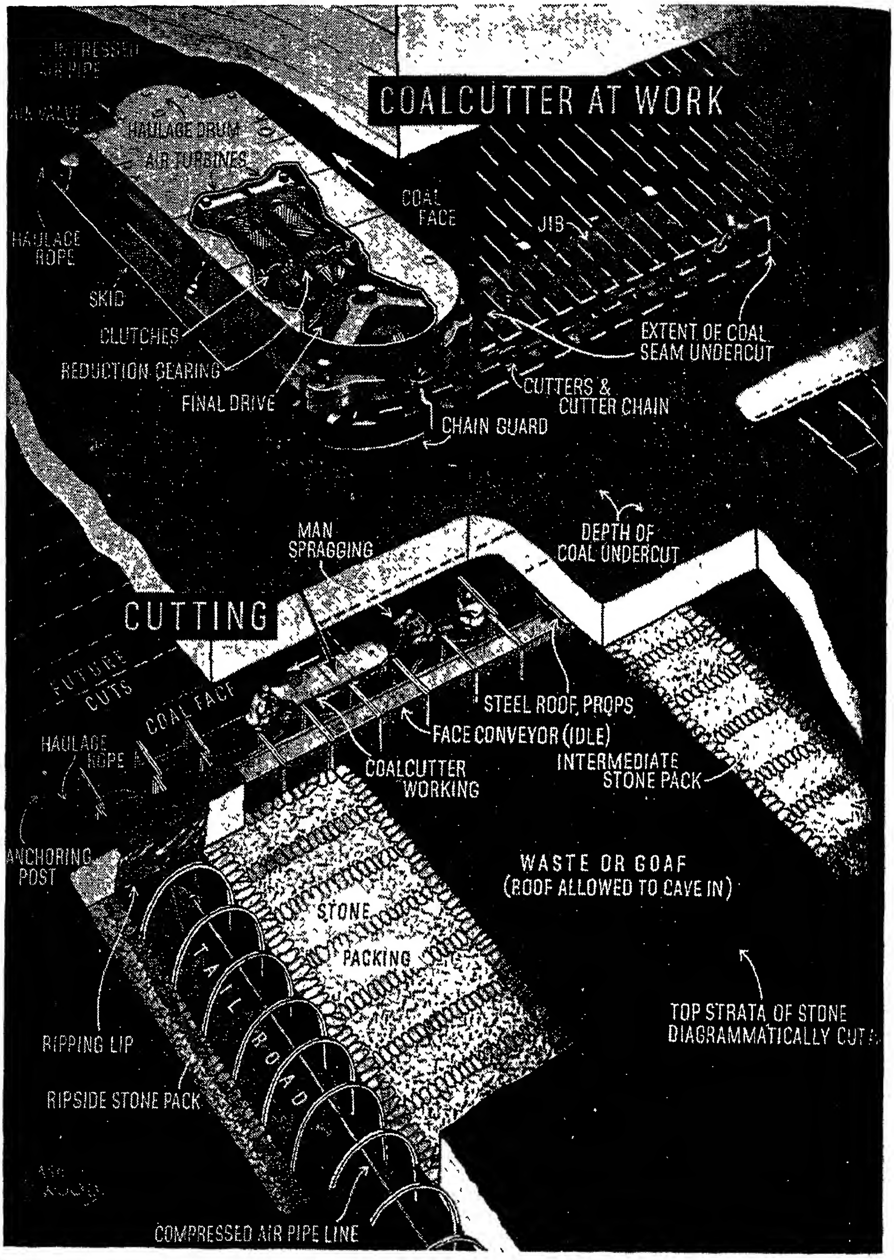
Filling a tub from the delivery end of a face conveyor, which brings the coal to the main gate direct from the coal face. After being filled the tub will be taken to the pit bottom by haulage, thence to the surface, where its weight will be recorded and checked.

see here, is called longwall working (Fig. 3). We keep a coal face, perhaps 200 yards long, which advances a fixed distance each day—it might be anything up to 6ft.—and a collier is stationed at intervals to win and fill out the coal.

Main gate road

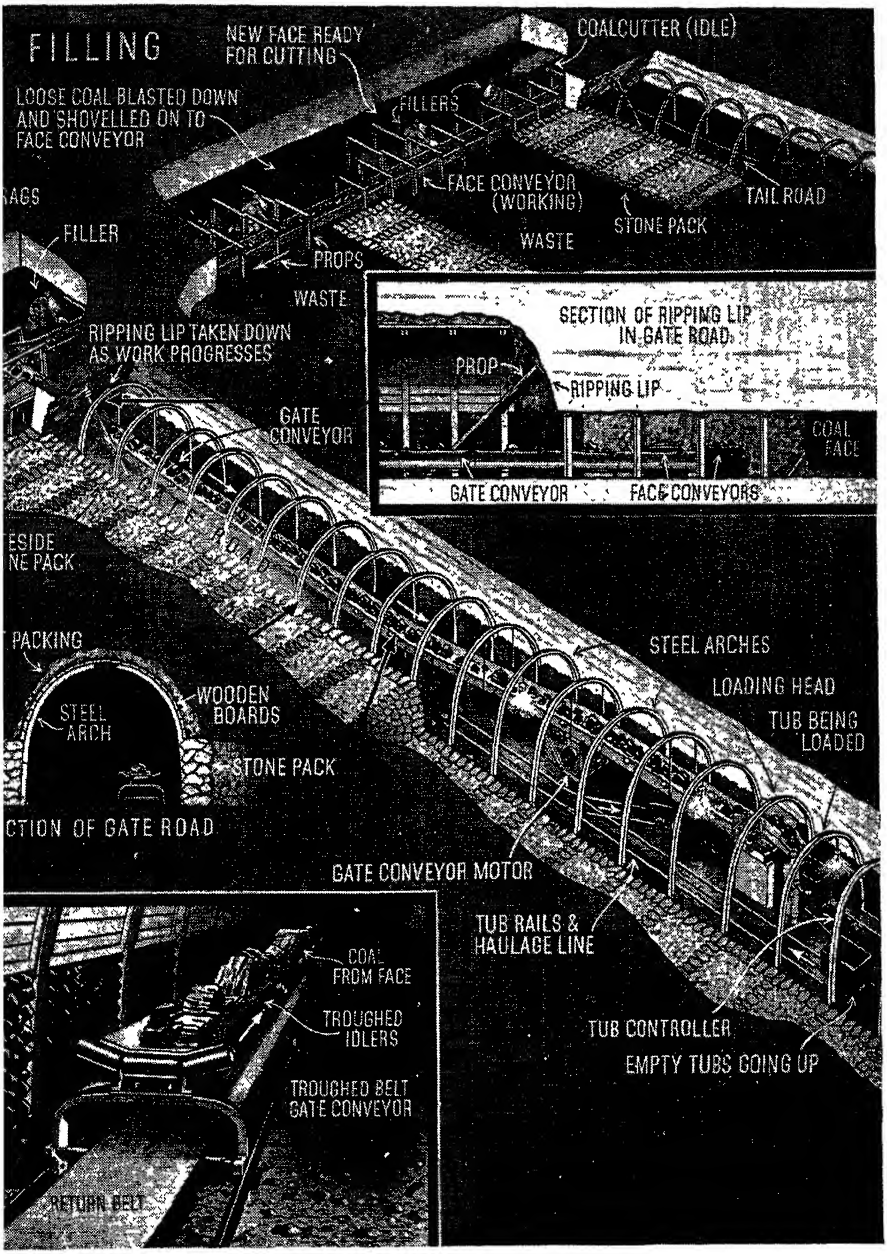
"The coal is brought away down a main gate road, leading from the middle of the face, and at each end of the face another road called a tail gate affords an alternative means of exit, allows for materials to be taken to the face, and provides for a ventilating circuit up through the gate road, along the face, and back through the tail gates and return roads. The other method is called bord-and-pillar working, and is used in broken, difficult ground and when mining under built-up areas. The seam is cut up by a series of longitudinal and transverse roads into squares, something like a gigantic chessboard, and these squares, or pillars, are then stripped as far as possible, but leaving enough coal to support the roof. This coal, of course, is lost if the surface has to be supported above, but the pillars are removed in strips and the surface let down if support is not required.

"Then there is the question of machinery. About two-thirds of the country's coal output is machine cut and mechanically conveyed; the rest is hand got. In some seams, too, the coal is shot down by explosives; in others it is won by hand or by pneumatic picks. You will see a coal-cutter at work."



COAL MINING BY THE

FIG. 3. *"One unit cutting and one filling" is the theory of this very practical method of mining. After the coalcutter (left) has ripped its way through the coal face, the coal is blasted or hewn down, and fillers (top right) shovel the loose coal on to the face conveyor. This automatically transfers it to the gate conveyor. On p. 36 is another view of a coalcutter with a worker at the controls.*



DOUBLE-UNIT LONGWALL METHOD

From the conveyor the waiting tubs are loaded for transmission to the surface. How the gate conveyor works is shown in an inset at base; while in the centre of the picture is a section showing how a gate road is constructed with stout steel arches, wooden boards and various packings. All of which play important parts in the highly organized system by means of which coal is won.

The paddy mail now draws up at its terminus, and we trudge forward along the road, in darkness except for the pool of light thrown by our lamp. We are watching the ground carefully to avoid stumbles, when a violent bang on our helmet brings us up standing. Two or three of the roof girders have buckled down wickedly under the roof pressure, and we realize that we have to watch both ends of our anatomy simultaneously if we are to avoid mishap. Eventually we turn off on a road inclining away to the right: a smaller road, so we walk with bent backs. There is a noise of machinery ahead. We reach what appears to be a low slot in the ground in front of us; are down on our hands and knees climbing into that slot; turn sharply to the left and are in a long, low gallery supported by steel props and roof straps. To our right is solid coal, to our left a belt conveyor, while the roof over our head slopes ominously downwards to meet the ground in the darkness to our left. We crawl forward, our helmet bumping against the roof straps and the palms of our hands grinding into the coal dust; we are at our immediate journey's end—the coal face.

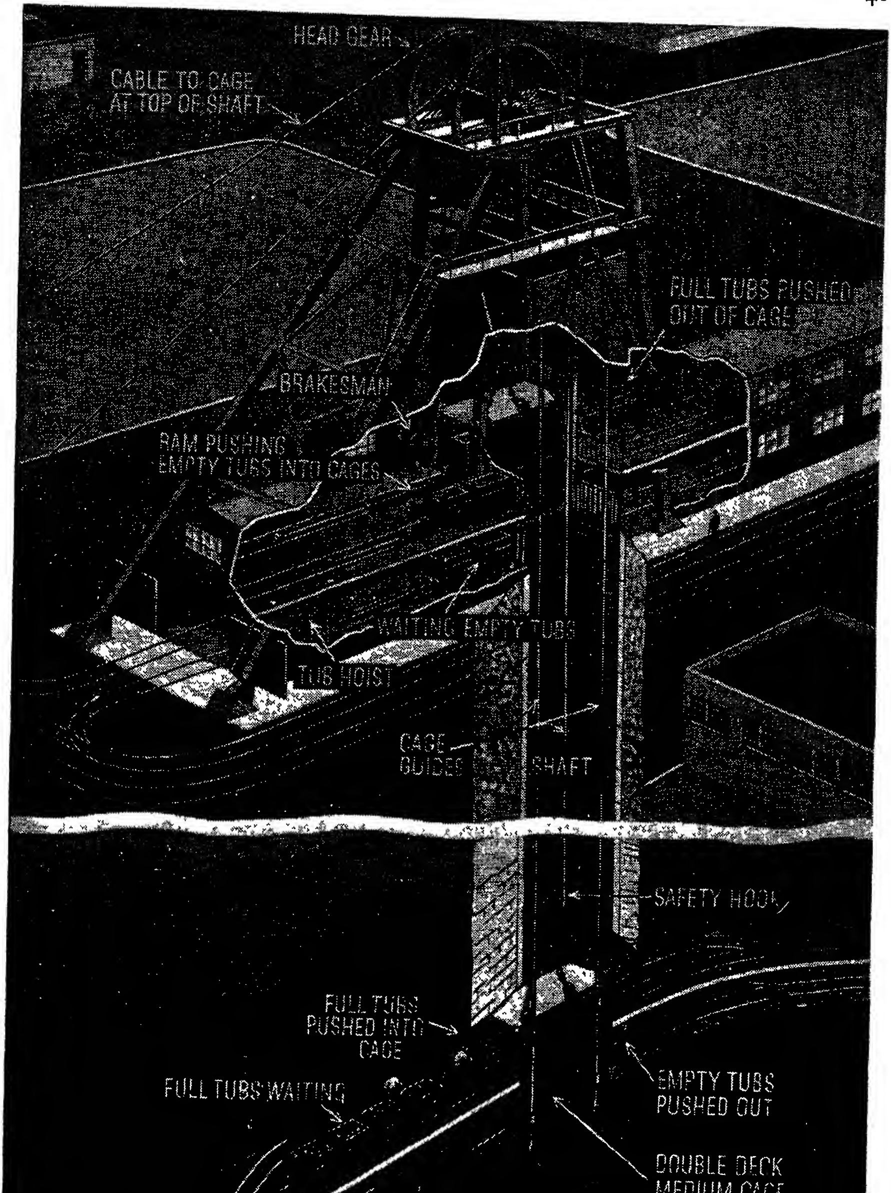
Mechanical coalcutter

Ahead of us is the coalcutter—a long, low steel box of a thing behind which the coalcutter man crouches at his controls (Fig. 2). He stops the machine and shows us how it works. A jib, round which is a moving chain fitted with pick points, extends under the coal at floor level, and is cutting a slot about 4in. wide and, say, 4ft. deep. A wire rope extends from a drum in the rear portion of the machine to a special anchoring prop, and the machine, as it cuts, gradually pulls itself along the face by hauling in the rope. At the jib end of the machine, a second man is clearing away cuttings and hammering sprags into the slot to keep the coal from dropping. A third man is removing props as the coalcutter reaches them, and restoring them as soon as the machine has passed. Farther along the face a man is drilling shot-holes. He has a portable electric drill mounted on an adjustable post fixed between roof and floor and carrying an augur which bores holes in the coal about 1¾in. diameter and nearly as deep as the slot cut by the coalcutter. "You should come again in the morning if you wish to see the rest of the operation," says the manager. "The night shift will come on later and advance the main and tail roads, build roadside packs, remove the back line of props, move the face conveyors close up to the face, extend the gate conveyor and do general roadway repairs." We decide to return.

The art of shotfiring

Accordingly, the following morning sees the manager and ourselves once more at the face, watching the activities of the shotfirer. He examines the shot-hole with a special tool to see that it is free from breaks, pushes in explosive cartridges, in the outermost one of which he has embedded an electric detonator, and fills the hole by ramming in a mixture of sand and clay. The art of shotfiring is to place one's shots and gauge the amount of explosive so that the coal is split without being smashed. Coal mining explosives are of special safety types in view of the danger of igniting gas. The shotfirer now tests the face for gas with his oil lamp, runs the detonator-leads to a refuge hole, and after making sure that everyone is in safety, attaches an exploder to the leads and operates it. There is a sharp thud followed by a rumble, and fumes are everywhere. These soon disperse under the influence of the ventilating current, and we find that the coal in the region of the shot is lying in a heap. The shotfirer tests again for gas, and if all is well proceeds to the next shot-hole.

The fillers now come on shift, and take



HOW COAL IS BROUGHT TO THE SURFACE

FIG. 4. *How full tubs are brought to the surface and empty tubs returned to the gate road far below by means of a double-deck cage is clearly shown in this illustration. Two-tiered, the cage enables simultaneous handling of the full and empty tubs, ensuring a continuous supply both ways.*

up station at intervals along the face, armed with pointed shovels. The conveyors are started, and each filler loads the loose coal from his section of face on to the conveyor. As he clears the face he sets a new line of props to support the newly exposed portion of the roof. The face conveyor carries the coal along the face to the main gate, where it discharges it on to the gate conveyor. We follow the gate conveyor down the gate road, and eventually reach the loading point where the coal is transferred to tubs (Fig. 5). We see in front of us two sets of rails, one for outgoing full tubs and one for incoming empties, and between each pair of rails is a steel haulage rope running on rollers. The gate conveyor ends in a jib which is centred over the "fulls" road, and is raised sufficiently to allow tubs to run underneath it. A boy is unclipping empty tubs as they arrive and pushing them over cross-over points so that they arrive under the jib. The coal falls from the end of the jib into the tub below it, and two youths control the filling operation (see Fig. 3 *right*).

Boys at work

As the tubs are filled, another boy couples them up into "journeys" of about half a dozen tubs and clips them on to the outgoing haulage rope. We trudge down the haulage road following the full tubs to the pit bottom. The tubs are travelling at only about 3 m.p.h., but there are refuge holes at short intervals on each side of the road. Our friend the manager points out the signal wires along the roadside by which signals for stopping and starting are transmitted immediately to the haulage engineman.

We reach a road junction, where the tubs are marshalled round points and sent forward on the main road to the pit bottom. Here the onsetter and his mates are marshalling the tubs in front of the shaft gates; and when a cage comes down they push the appropriate number of tubs into the cage, driving the empty tubs out of the cage on to the rails on the far side of the shaft—then a rap on the bell knob and the cage is away (Fig. 4).

In due course a pause is made in coal drawing to allow us to travel to the surface, where we see the reverse procedure in operation. A cage comes up with a crash, the banksman pulls a lever, and, with a terrific clatter, powerful rams push the empty tubs into the cage and drive out the full tubs before them. The banksman rings to the engineman, the onsetter rings from the shaft bottom, and the cage drops like a stone to an accompaniment of slamming gates. It is all over in a few seconds.

Weighing and screening

We follow the full tubs along a gantry, where boys are marshalling them round curves, over points, and along to the weigh cabin. Here the weight of each tub is recorded by two men, one being the checkweigher—a man employed by the workers to check that all weights are taken and recorded correctly. Weighed, the tubs pass forward to the screening plant where they are discharged by tipplers—rotary cages which turn each tub completely over and empty its contents into a hopper feeding the screens immediately below. Further boys marshall the empty tubs round a loop back to the cage gates. We clamber downstairs to examine the screens—giant mechanical sieves which sort the coal into "large," "cobbles," "nuts" and so forth.

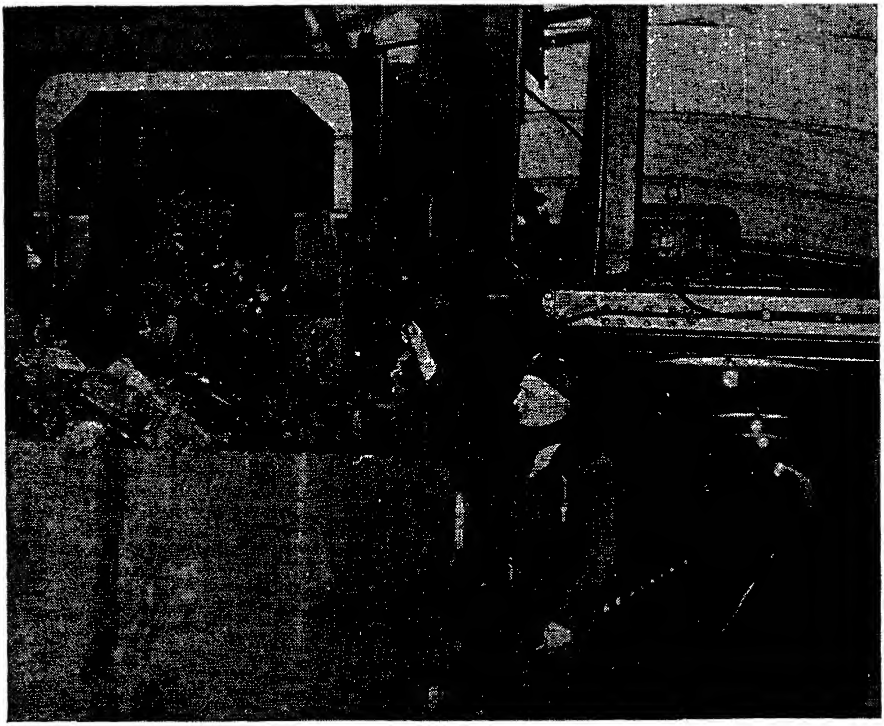
Each size of coal is discharged to a long slow-moving belt—usually made of steel plates—on either side of which men and boys are standing, examining the coal as it passes them, and removing any stones or inferior coal that they may find. These are the picking belts. Each picking belt terminates in a movable jib which discharges the coal into a railway wagon

which stands immediately below. A boy watches the loading of these wagons, raising and lowering the jibs as required, and when a wagon is full he performs a cadenza with an iron bar on a piece of steel plate hanging from a convenient joist. The wagon man can hear this devil's tattoo even above the noise of the screens, and changes wagons accordingly.

How coal is washed

The manager now takes us across a gantry to the washery, where, he tells us, coal below about 4-in. is cleaned. This, to us, astonishing statement comes as something of a shock.

"*Cleaned?*" we exclaim incredulously, "But we always thought coal was the essence of filthiness!" The manager smiles, and explains that coal as mined is inevitably mixed with a proportion of stone, shale and dirt, either picked up from the floor or embedded in the coal seam itself. This will not burn and must be removed. In the larger sizes it can be removed by hand picking, but the smaller sizes have to be cleaned. "There are many methods of cleaning coal," he tells us, "but they divide into washing processes and dry-cleaning processes, and most of them depend on the fact that stone is much heavier—or, strictly speaking, denser—than coal. In coal washing, conditions are arranged so that the coal is actually floated on the water while the dirt sinks to the bottom. In dry



FROM GATE CONVEYOR TO TUB

FIG. 5. *Coal is being filled into tubs after having been brought from the workings by the gate conveyor. This loading station has a shaking delivery chute which enables the attendant to control the filling operation to a nicety. The full tubs will be hauled to the shaft bottom.*

cleaning, the coal is passed over a vibrating table and a strong current of air blown up through it from holes in the table. This has the effect of making the coal bed 'fluid' and allows the stones to sink to the bottom of the bed."

In the washery, the washery foreman is watching the behaviour of a large tank through which coal is being passed, the water being kept in motion by a pulsating action which floats the clean coal to the top and over a weir to dewatering grids. The coal is then screened into the various sizes of "washed smalls" generally required by industrial consumers.

Making a wind

At this point a messenger tells the manager that H.M. Inspector of Mines has arrived, so the manager begs to be excused, and we are piloted off to make the acquaintance of the chief engineer. He shows us round his boiler plant, power plant, ventilating fan, and repair shop, and finally takes us into one of the winder houses. Here a giant of a steam engine is driving a rope drum about 20ft. in diameter, and an imperturbable individual, in shirt sleeves and seated in a wooden chair of state, is presiding over a number of large levers, watching various indicating dials.

We watch him "make a wind." A bell makes two strokes, and a pointer on a dial marked "Banksman" jumps to "Lower." Another bell rings one stroke, and the pointer of a second dial marked "Onsetter" moves to "Raise." The engineman takes off the brake, throws over the reversing lever and applies steam; the engine springs into life. A large pointer creeps round a dial, showing the exact position of the cage in the shaft. About a third of the way through the wind the engineman shuts off steam, and, after about two-thirds of the wind, throws over his reversing lever and applies steam against the engine to slow it down. The final turn or two is taken at a crawl, and the engine is brought to rest with a white mark on the drum exactly in line with a pointer on the engine frame. On a later occasion three rings are given for "men winding," and the engineman throws over a lever which adjusts the safety devices more closely and compels him to wind at a lower speed. The engineer tells us that many winding engines are electric, and they can be made partially, or even completely, automatic.

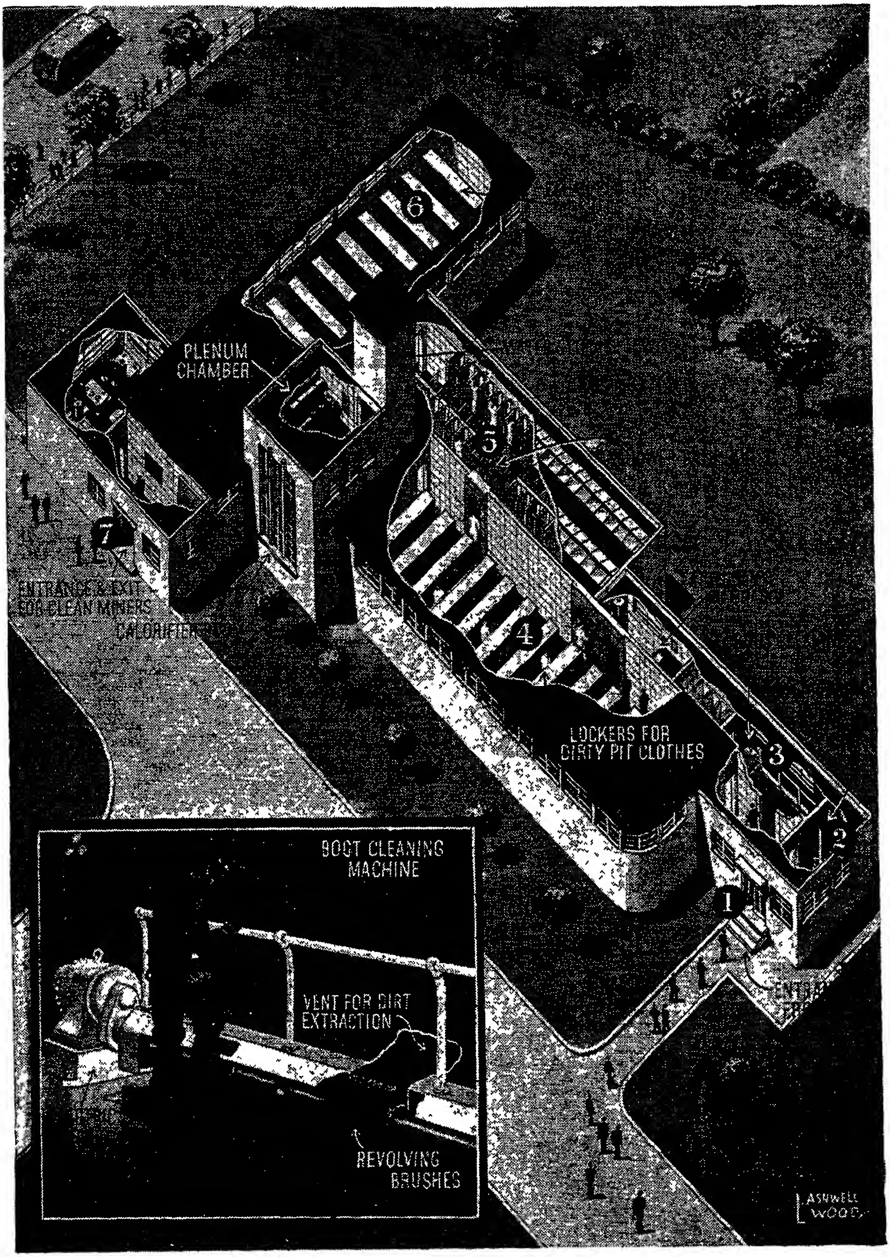
We have a few moments to see the colliery surveyor, who explains that it is an official requirement to keep a plan of the underground workings, and it is part of his task to ensure that this plan is accurate and up-to-date. He has to do the necessary surveying for the opening out of new workings, and has to correlate the underground plan with the surface plan and the Ordnance Survey, so that the position of all underground workings in relation to surface features shall be accurately known.

Mines Inspectorate

The surveyor explains that all coal mines are subject to regular supervision by a Mines Inspectorate under the Coal Mines Act, just as our factories are supervised by inspectors appointed under the Factories Act.

There is a Chief Inspector of Mines at headquarters in London in charge of eight inspection divisions, consisting of a Divisional Inspector aided by a staff of senior and junior inspectors among whom the collieries in the area are allocated.

Visits by inspectors are unannounced and may even take place at night. In this way a constant check is kept upon working conditions and safety precautions. Should anything unsatisfactory be found, it is brought to the manager's notice and measures suggested which should have the effect of putting it right.



WHEN THE DAY'S WORK IS DONE

FIG. 6. *At many pitheads, the miner has special facilities for bathing and changing into the home-going clothes which, warmed and dried, await him. Automatic devices for cleaning boots are supplied and, for such as wish it, a canteen provides welcome refreshment in a modern setting.*

METAL IS BORN

In this impressive scene, so strikingly suggestive of the potentialities of a great industry, white hot, molten metal pours out hissing into the moulds placed ready to receive and shape it.

IRON AND STEEL SINEWS OF INDUSTRY

By ROBERT WILSON

Largest of the "heavy industries." Night and day shifts. Blast furnaces—how iron is extracted from ore. How castings are made. Open hearth furnaces, Bessemer converters and electric furnaces. Ingot casting and "stripping the ingot." Rolling, casting and forging. Tensile testing. The wonder of modern steelwork revealed.

MR. SMITH, whose name betokens some dim ancestral interest in the subject, knows well enough that Britain's iron and steel industry has behind it an industrial army equal to any in the world. But, unless he happens himself to be engaged in the craft, he may not know much about it. If he happens to be so engaged he will not need telling that the personnel of all grades consists of well-defined types; whether iron-ore miners, smelters, heaters, rollers, forgers or casual helpers with generations of experience behind them. Mr. and Mrs. Smith are, or should be, proud that iron and steel production has not only been maintained but increased by the valiant efforts of women in jobs which, before the second world war, were regarded as totally unsuited to them. The best testimony to their efficiency and achievements has come from men with upwards of 40 years' experience in iron and steel production, who, while looking upon the advent of women with some degree of chagrin, have expressed themselves as amazed at what women have been able to achieve. True, as we shall see, there are some jobs calling for great physical strength and endurance, which they could not be expected continuously to undertake; though these are fewer than might have been imagined. The iron and steel industry is by far the largest of the so-called heavy industries and official figures showed that the pre-war value of the annual turnover was just under three hundred million pounds sterling.

Iron and steel production consists of appropriately timing a number of processes that are carried on uninterruptedly night and day. Many blast furnaces, in which the iron is extracted from the iron ore, have been "blowing," or in continuous operation, for years. In fact in normal times of good trade they are only "blown out" when repairs are needed. So work goes on.

Night and day "blowing"

To achieve this continuous operation it is customary to work three shifts, or turns, per twenty-four hours, usually from 6 a.m. to 2 p.m., 2 p.m. to 10 p.m., and from 10 p.m. to 6 a.m. Workers engaged on continuous operations normally do one week on each of the different shifts although, by mutual arrangement, some men work permanently on the same shift. In many jobs, steel melting, for example, it is a point of honour that a man shall not leave his post until relieved by his mate or opposite number, thus proving their sense of responsibility.

Iron smelting is mostly restricted to the vicinity of the coalfields and is carried on in Scotland, north-east and north-west

England, the Midlands, Lincolnshire, and South Wales. With the advance of scientific knowledge, raw coal is no longer used as fuel and coke has taken its place. This coke is usually manufactured at the iron works where finely-sized coal is introduced into suitable vertical ovens and raised to a high temperature when the "volatile matter" is driven off. After a suitable period the incandescent mass in the oven is discharged by a mechanical ram into a steel wagon known as a quenching car or "larry," and quenched under strong water jets, when huge clouds of steam are driven off. The resulting coke is then tested for hardness, resistance to crushing and other properties, and graded according to size and quality. Many advantages accrue from the use of a uniform quality of ore and coke although, at times, it becomes necessary to blend good with bad.

Blast furnace in action

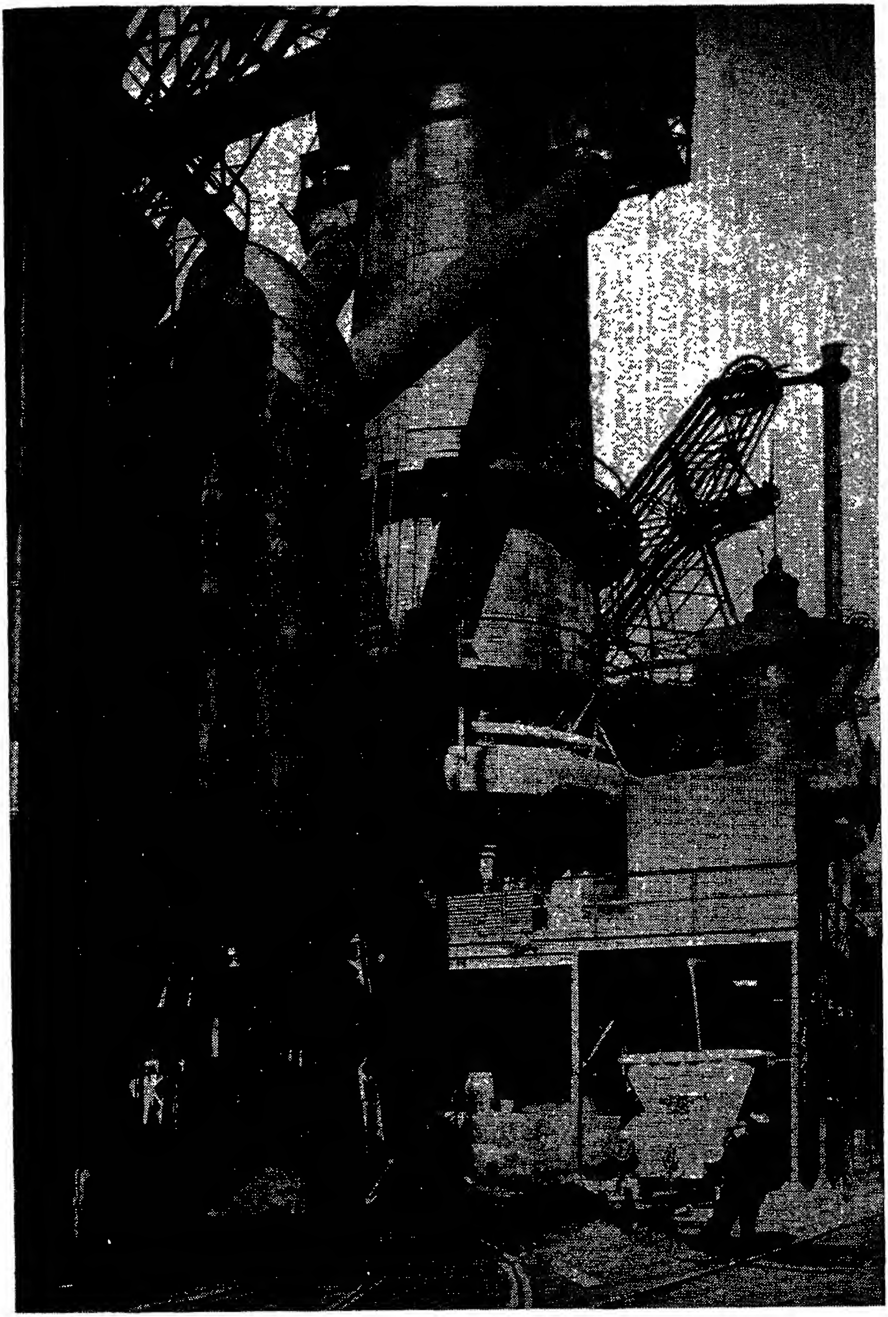
The only other important raw material required before proceeding to the smelting operation is called a "flux," which is usually limestone. This flux is introduced because of the various impurities inherent in the iron ore. What happens is that under the influence of heat, the flux melts and dissolves out the impurities, forming a scum or slag, which, being much lighter than iron, floats on top of the liquid iron and is easily separated. Once the ore, fuel and flux have been charged into the blast furnace, in carefully calculated proportions, they become known as the "burden."

One may now look at the blast furnace where the iron is extracted from the ore. This is generally known as a vertical stack, circular in shape, and built of brickwork or masonry and braced with iron plates (Fig. 1). Its height may be over 100 ft. The materials which go to make up the burden—the ore, coke and limestone—are introduced at the top of the furnace, which means that some form of hoist is an essential part of the plant. The air necessary for the combustion of the coke, and the consequent separation of the oxygen from the ore, is introduced under pressure near the foot of the stack or furnace. It is of interest to note that this air, known as the blast, is pre-heated to speed up the smelting operation. As the burden gradually descends in the stack the temperature increases, and the metallic iron liberated from the ore falls in large droplets into a specially constructed well at the bottom of the furnace.

By-products from smelting

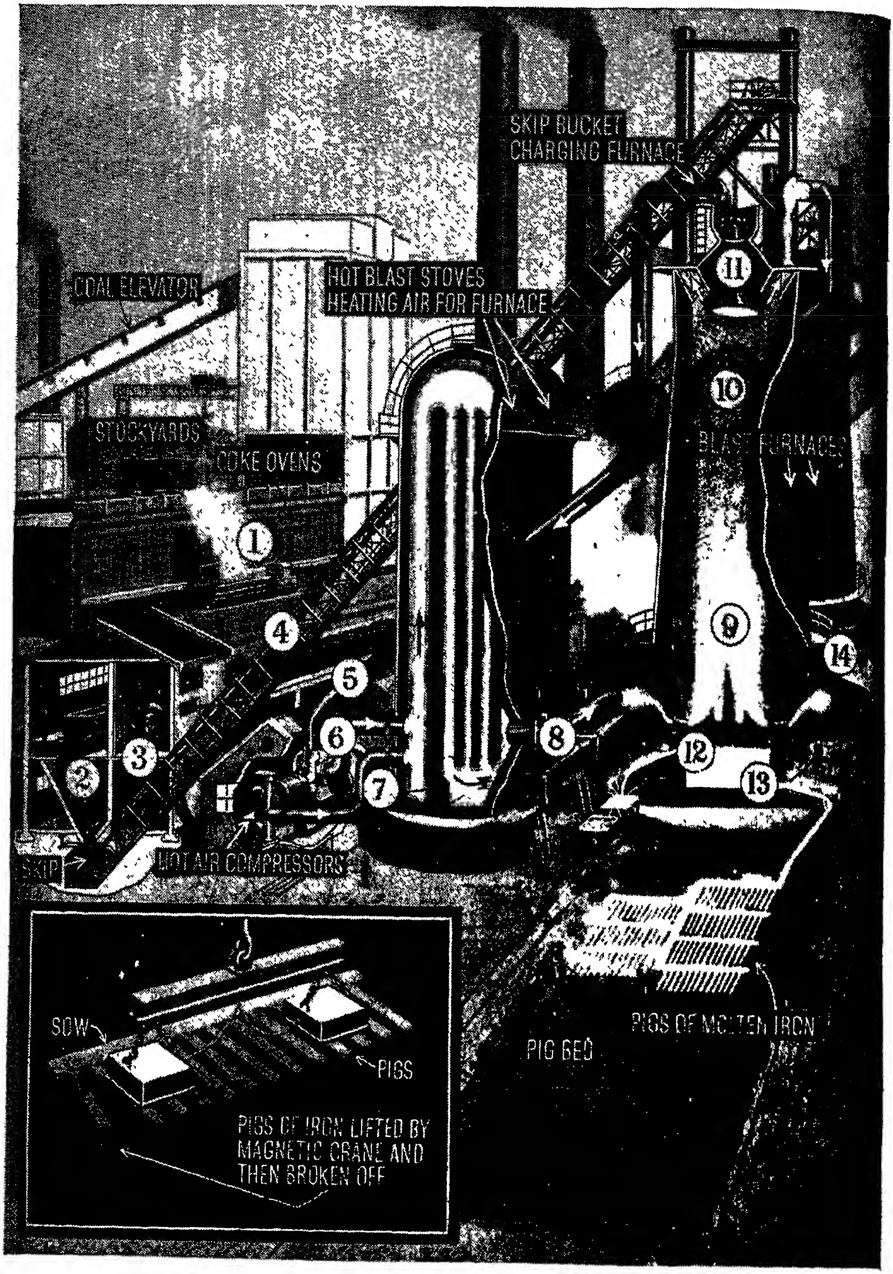
During the smelting operation a large amount of gas is given off which is directed into other departments where it is employed to heat boilers and furnaces. Other by-products recovered from the coke-ovens and blast furnaces include tar, benzol, sulphate of ammonia, etc.; while a certain proportion of slag is used in making roads and cement. There was a time when nothing was recovered and even the gas was allowed to burn to waste at the top of the furnace. That is why it used to be said that certain towns in England and Scotland were never dark.

When the molten iron in the well of the blast furnace rises to a certain level, the furnace is tapped and the iron allowed to run off freely into either a steel ladle lined with firebrick or direct into sand beds adjacent to the furnace. These beds are usually made by a template, called a "comb" because of its likeness to the ordinary hairdressing article, although of rather gigantic proportions. As soon as all the iron (and the slag) has been tapped or run off, the tap-hole through which the iron has been allowed to flow is sealed up again with a plastic refractory mixture—that is, something that will withstand heat—by means of a "gun," a mechanical contrivance which does the job quickly and efficiently thus reducing the amount



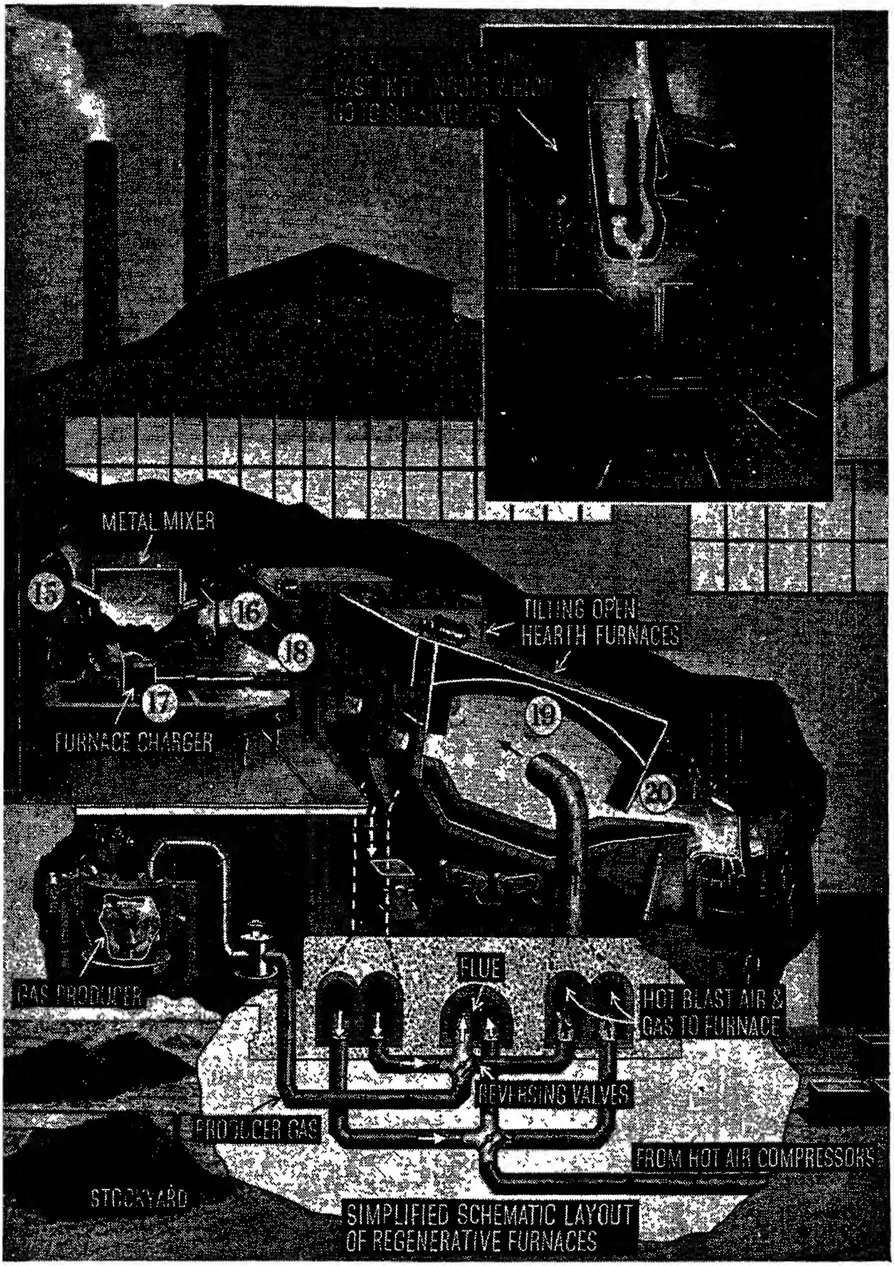
WHERE ORE YIELDS IRON

FIG. 1. *Towering like some fantastic castle, this enormous blast furnace changes its "burden" to metal, the iron liberated from the ore falling in droplets into a well at the bottom of the furnace.*



PIG IRON FROM BLAST FURNACE:

FIG. 2. *1, coke quenching car; 2, coke, limestone and ore hopper; 3, skip hoist engine; 4, charging skip to blast furnace; 5, hot gases from furnace; 6, hot gases to blast stove; 7, hot air to blast stove; 8, hot blast main; 9, iron being smelted from ore; 10, ore, coke, and limestone.*



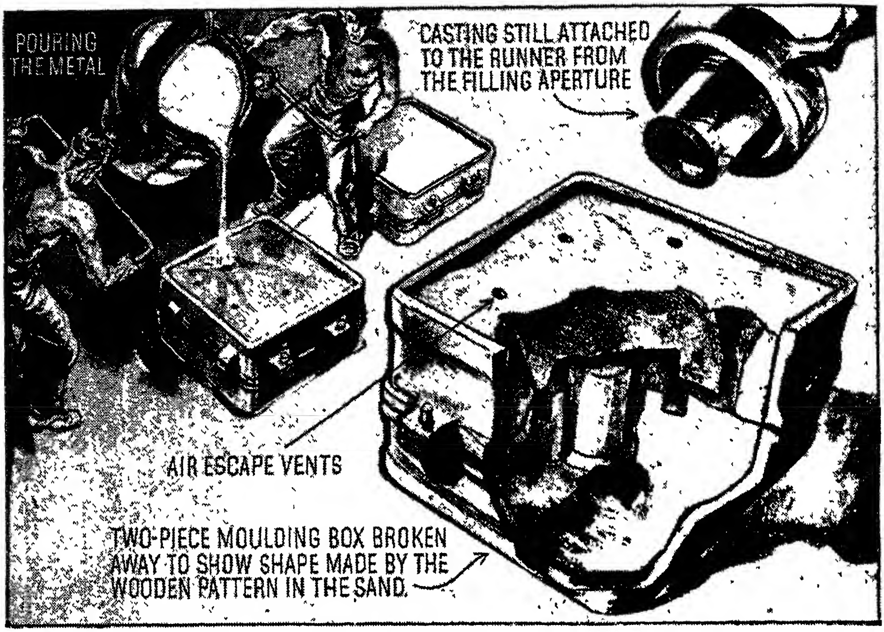
STEEL FROM OPEN HEARTH FURNACE

11, charging cones at work; 12, slag outlet; 13, tapping molten iron; 14, molten iron for steel making and (15) poured to mixer; 16, iron for open hearth furnace; 17, scrap steel, etc., charged into furnace; 18, charging furnace; 19, tapping furnace; 20, molten steel poured to ladle.

of manual work performed by the furnace-man. The iron poured into these sand beds is known as "pig-iron" (Fig. 2).

When the iron is poured direct into a ladle it may be cast into "pigs"—convenient uniform sizes to handle—in a pig-casting machine, consisting of moulds of

Pig-iron may be described as an intermediate product, or crude iron from which other articles are made, its principal uses being (1) for the manufacture of iron castings in foundries, (2) the manufacture of wrought iron, and (3) the manufacture of steel which is, by far, its



HOW A CASTING IS MADE

FIG. 3. *Packed with sand in which the shape of the desired casting is impressed by a wooden model, the box has molten metal poured into its filling aperture. When cool, the casting is removed, cleaned and dressed, and the superfluous metal, collected in the filling channel, cut away.*

appropriate size mounted on a long endless chain. This is more modern practice than the use of sand beds and has the great advantage of saving ground space and labour, for the moulds are permanent and the pig-beds do not have to be remade each time; further, the "pigs" can be tipped from the endless chain direct into wagons, thus saving the time and energy expended on loading. Sometimes, of course, the pig-iron is not allowed to solidify but is taken in the ladle direct to the open hearth or Bessemer furnaces for conversion into steel.

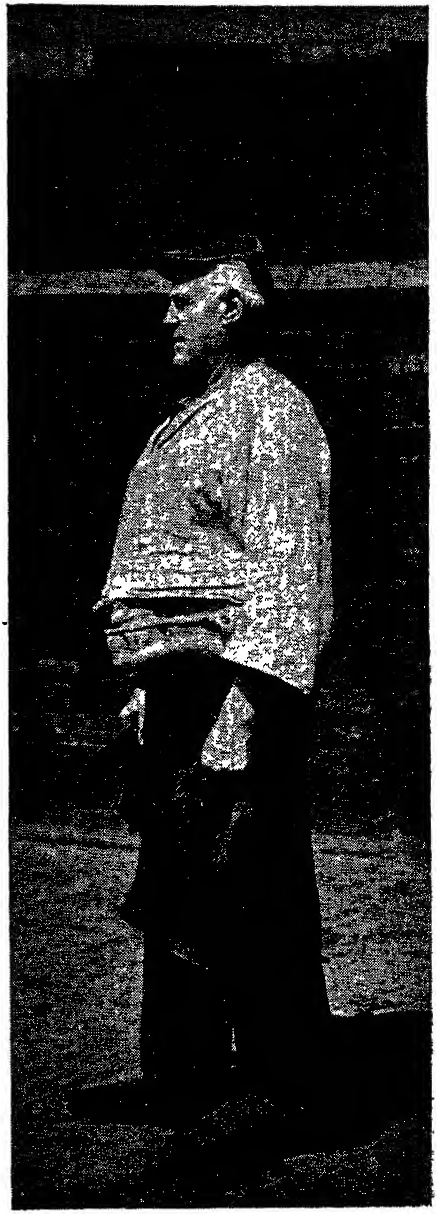
largest and most general use.

When pig-iron is used for the manufacture of iron castings in a foundry, the pig-iron is melted in a furnace of the cupola type and tapped into a ladle, when it is poured into a sand mould of the required shape (Fig. 3). To make this mould it is necessary, first of all, to prepare a pattern, usually in wood although other materials are employed, of the exact shape of the article required. To facilitate moulding, the pattern is usually made in halves known as "top" and "bottom." Sand is then firmly

rammed, by either machine or hand, round the halves of the pattern in some sort of framework known as a "box." When the sand has been moulded to the exact shape of the pattern the latter is removed, the necessary cores inserted and the box closed. Closing the box means totally enclosing the sand impression by putting the two halves together, so that it will hold the molten metal in such a way as to give an exact replica of the pattern—due allowance being made for the contraction of the metal as it solidifies. Cores, it should be explained, are made of sand which can be removed later, and are used to leave any desired hollow or space inside the casting for the free passage of gas or liquid. After the metal has solidified, the sand is broken away and the iron object, now known as an iron casting, is removed for further treatment. The casting is then cleaned or dressed and the heads or risers through which the metal was introduced to the mould cut off. These risers have other very important objects: (1) to allow air and other gases to escape when the mould is being filled; and (2) to supply a reservoir of metal, for it is well-known that when iron or steel cools it contracts, and unless a mould can be fed from such a reservoir an unsound and unacceptable casting will result, involving avoidable wastage.

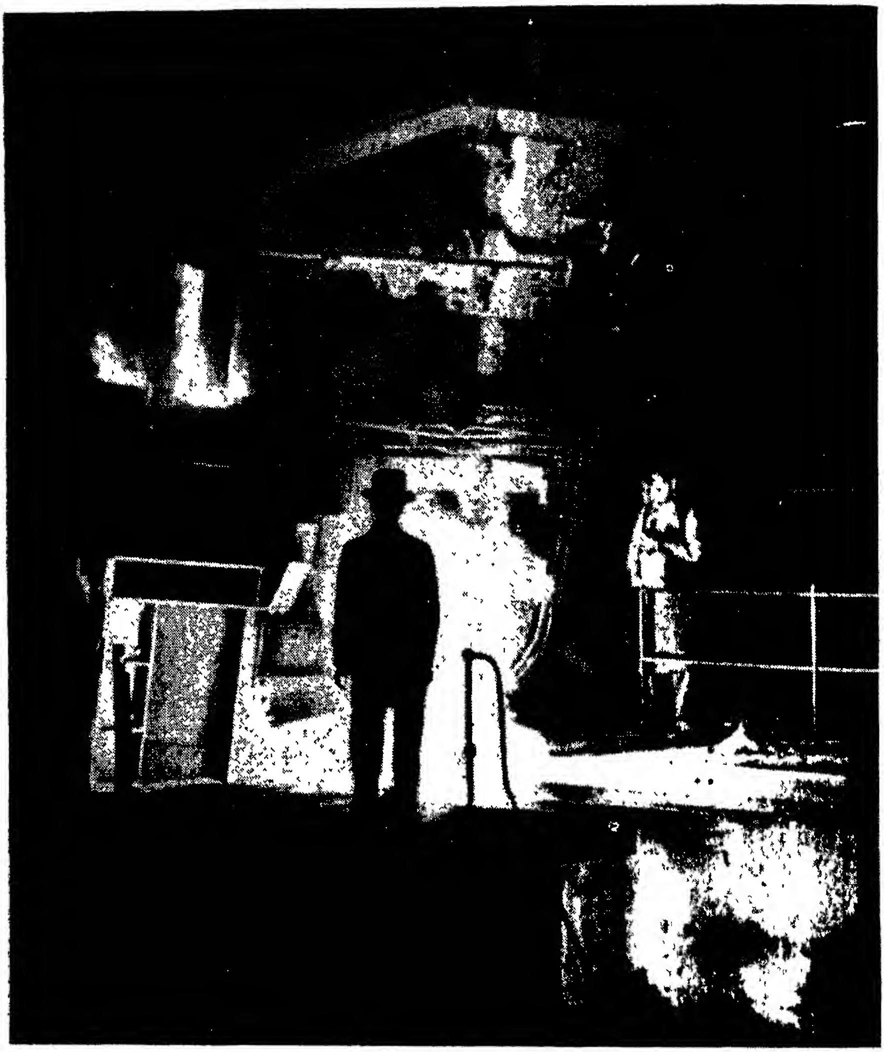
Puddling and shingling

For conversion into wrought iron or merchant bar, pig-iron is introduced into a puddling furnace and worked into a pastry ball during which impurities are removed. It is never actually melted. At the end of the process, which the skilled eye of the puddler can determine, the mass is removed from the furnace when it is "shingled," that is, hammered into a bloom or billet under a steam hammer. The resulting billet is then rolled into bars in a mill when the product is named



ARMOURED SHINGLER

Picturesquely armoured against intense heat, a shingler goes to his job of steam-hammering the puddled metal into "blooms" or "billets." These are next rolled into "merchant bar," a product better known to us as wrought iron.



TAPPING AN ELECTRIC FURNACE

Silhouetted against the vivid glare of molten steel, workers superintend the tapping of an electric furnace which, tilted, yields its contents. Heat in electric furnaces—mainly used for special steels—is provided by an electric arc or—in the smaller furnaces—by induction.

"merchant bar." This product is relatively soft and very tough, enabling it to be employed for a variety of uses.

Puddlers and shinglers are not so numerous now as a few decades ago. Their work is heavy and calls for craftsmanship of the highest order.

The most important use of pig-iron is undoubtedly for conversion into steel. Although in use for centuries, steel has never been adequately defined, but is commonly regarded as an alloy of iron and carbon, the latter exerting a very great influence upon the iron, depending

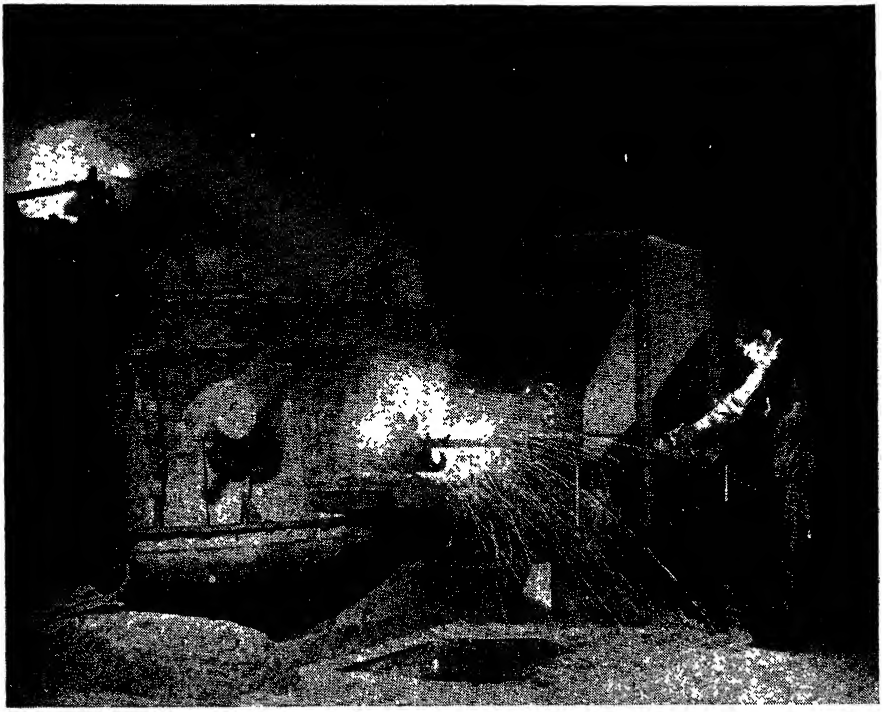
upon the amount of carbon present. In fact, the carbon may range from about 0.10 per cent. up to nearly 1.8 per cent. Most common steels, however, contain less than 0.5 per cent.

Better and stronger steels

Steel is to be found in machinery of all descriptions and there are thousands of varieties all with different properties depending upon the elements or alloys which have been intentionally added to achieve desired properties. An idea of the size of the industry in Britain may be gathered from the fact that the yearly output is upwards of twelve million tons. Some of the largest consuming industries are railways, ship-building and structural and general engineering. The annihilation of distance by faster ships, motor vehicles, aeroplanes, and even telephones and radio, results from the manufacture of better and stronger steels. Britain, even in the face of severe competition from foreign countries which manufactured steel of a low grade, has always paid the utmost regard to quality and, at any rate in modern times, has always been pre-eminent in this respect.

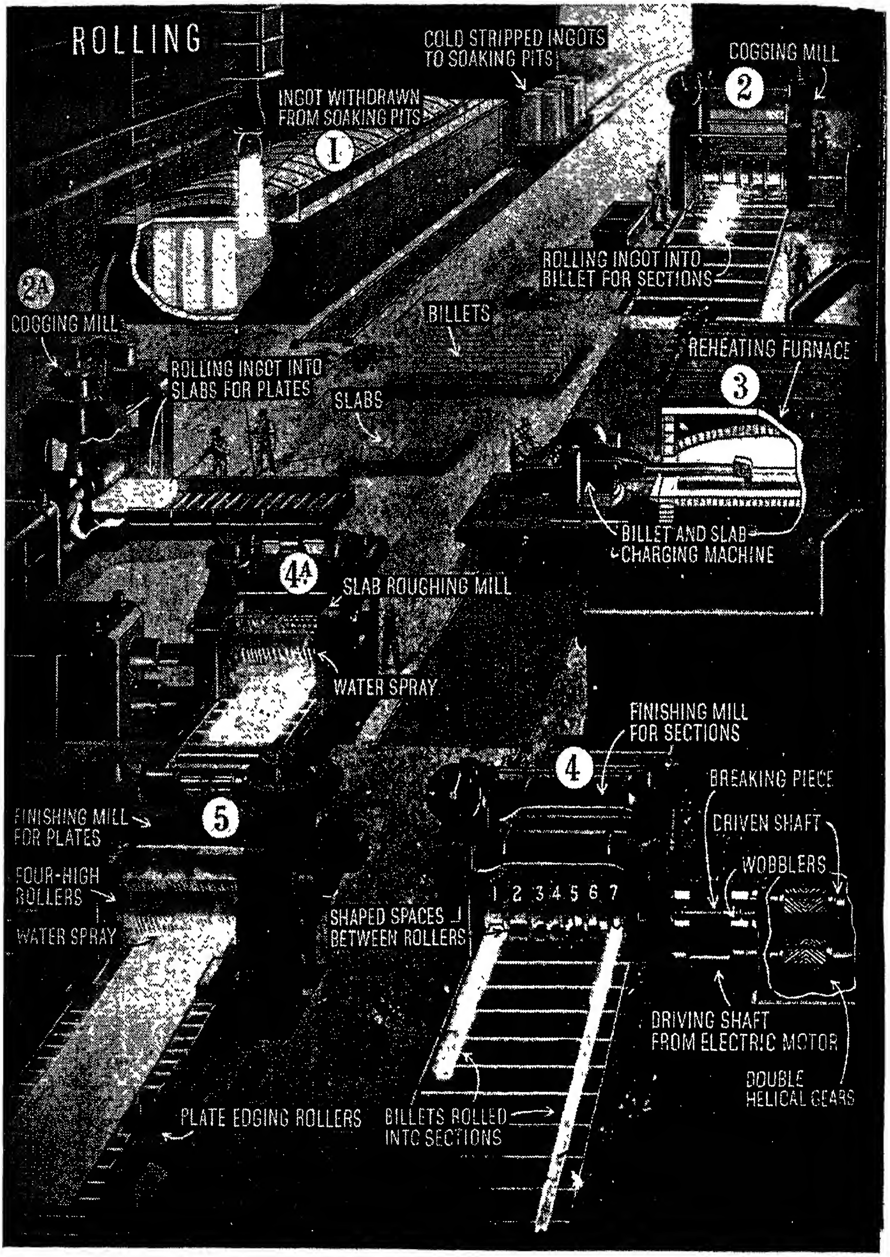
Principal types of furnace

The principal furnaces employed in the manufacture of steel are the open hearth, the Bessemer converter, and various types of electric furnaces. The open hearth (Fig. 2) is the process almost universally



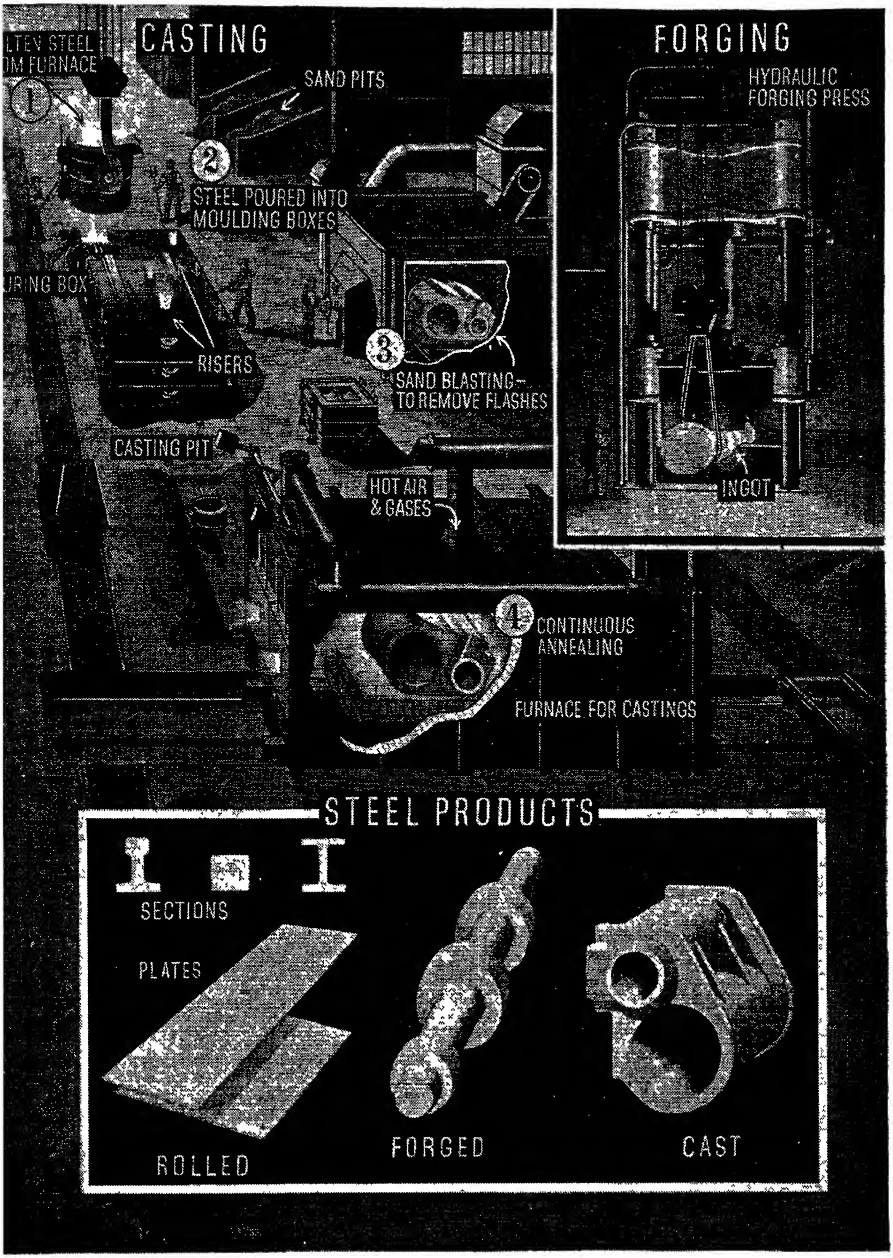
ELECTRIC ARC FURNACE IN ACTION

Here, in one of Britain's largest engineering works, is an electric arc melting furnace which with 16 charges of 7,000 lb. gives 12 hours smelting sufficient for 10 pouring. Metal is tilted from the furnace into a reservoir from which it is tilted into hand ladles for the moulds.



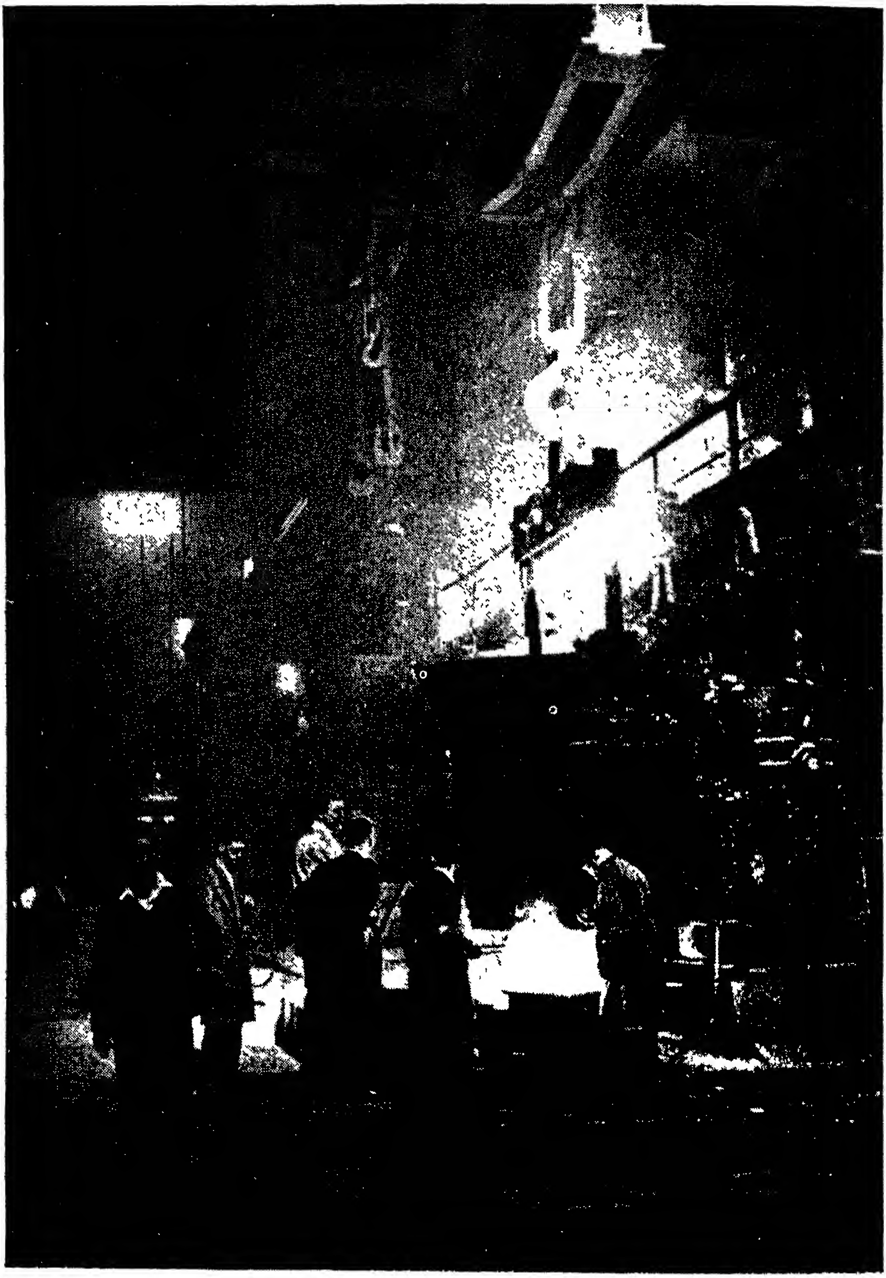
FINAL STAGES IN STEEL MAKING:

FIG. 4. *In this view of an imaginary but typical factory is indicated the sequence of mechanical working operations in a rolling mill. From the arrival of the ingots to the rolling of billets into sections and the finishing mill for plates, the order of processes is simply demonstrated by the artist.*



ROLLING MILLS AND CASTING SHOP

On this page we can follow the process of casting and subsequent treatment, while at top (right) is inset a typical forging press. In another inset (below) are seen typical products of a steelworks, respectively rolled, forged and cast and ready for further machining or assembly.



HOW INGOTS ARE CAST

FIG. 5. *From a huge suspended ladle, metal is "teemed" into moulds in a pit below floor level. After the steel has solidified, the moulds are removed from the masses of metal now known as ingots. "Stripping the ingot" is the technical term for this process. Next comes rolling or forging.*

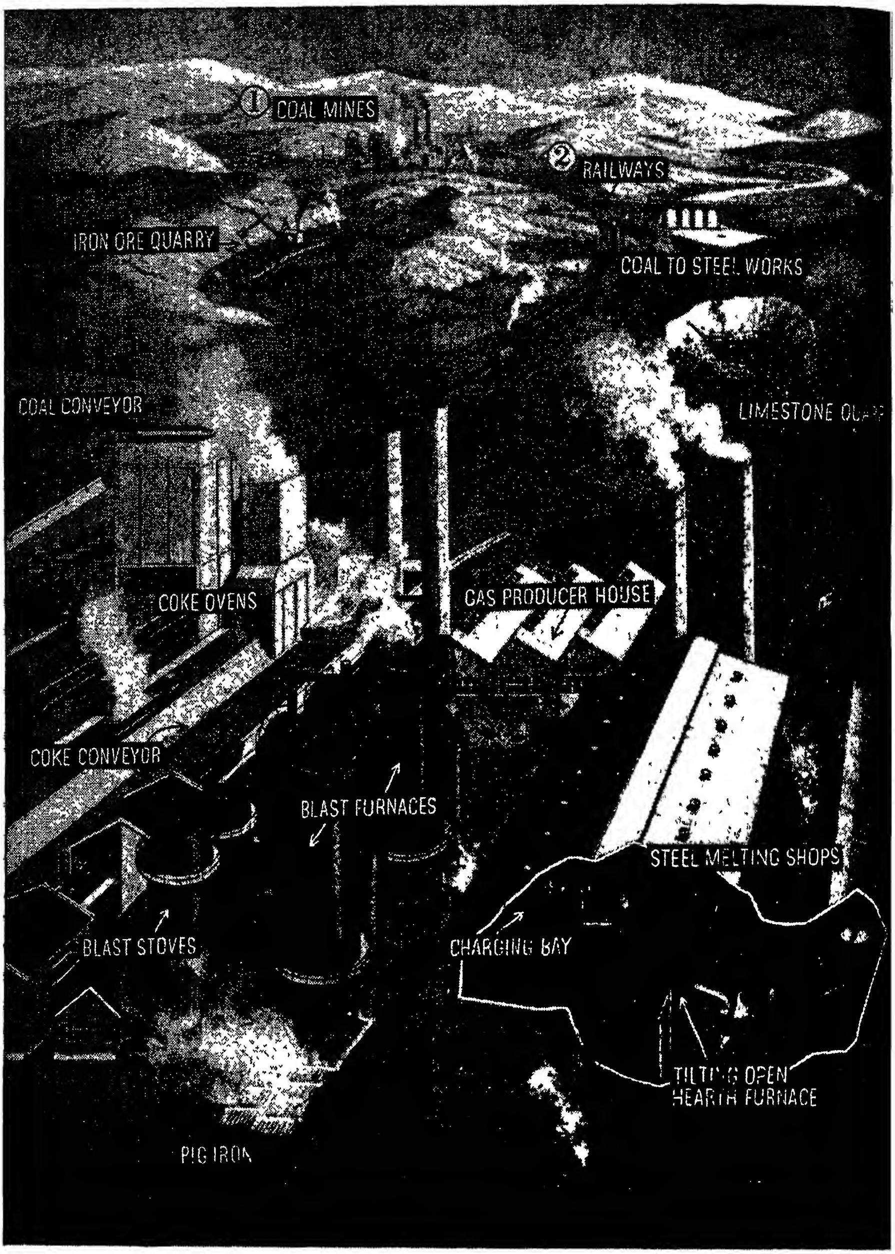
employed in Great Britain, though there are a number of Bessemer plants in successful operation. There are also numerous electric furnace plants, but these are almost exclusively employed on the manufacture of special steels—so-called because of the alloys they contain and the properties they possess. Electric steels, as they are termed, have usually to withstand rigorous working conditions.

Open hearth process

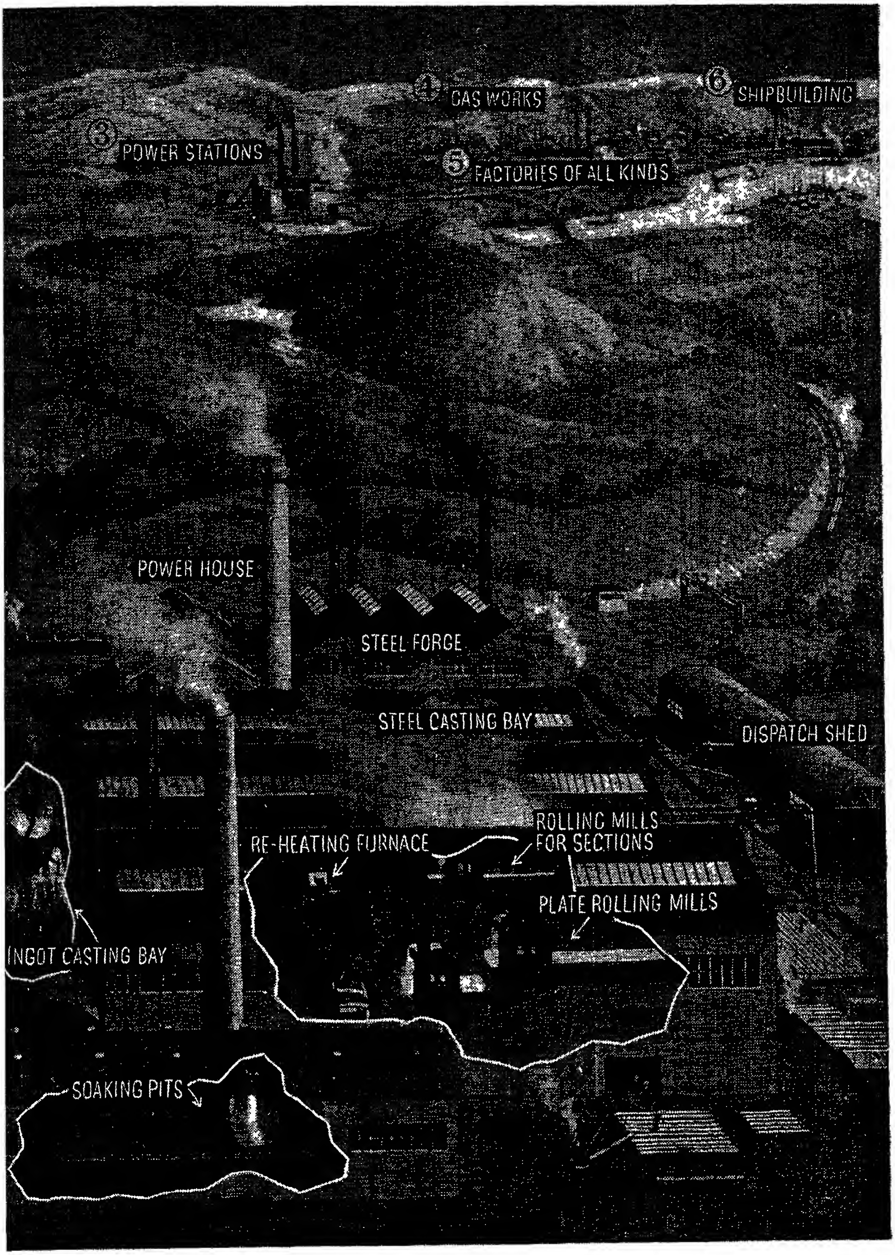
The open hearth is heated with coal gas made in the works in retorts known as gas producers. In steel works where there are no blast furnaces, cold pig-iron and scrap steel are charged on to the operating hearth, or bath, where the whole charge is melted and refined. Refining consists of the elimination of excess carbon and other elements by a process of oxidation, which is really combustion or burning, and bringing the metal to the desired composition. At this stage the chemist and melter work hand in hand. During the process samples of the molten metal are withdrawn from the furnace by means of a long iron "spoon," and tested in the laboratory. As a result of very rapid methods of chemical analysis carried out by expert chemists, the melters know exactly how the reactions involved in the refining process are proceeding. When the end point has been reached, the metal is tapped into a brick-lined steel ladle similar to that employed at the blast furnace, when it is cast into ingot moulds. These furnaces are built to a definite capacity which may be from 30 to 100 tons per charge, and the process is continuous, being operated on the three-shift system. One point of difference between the continuous operation of the blast furnace and the open hearth is that the latter, being more amenable to control, can be damped down at the week-ends, the men usually stopping on a Saturday morning and resuming again on Sunday night. During the week-end, "watchers" or skeleton crews remain on duty. The procedure just outlined is known as the cold pig-and-scrap process. In an integrated works however—these are works where both pig-iron and steel are produced—the pig-iron from the blast furnace, as previously mentioned, is never allowed to cool and is taken direct from the blast furnace to the open hearth. This practice eliminates much manual work and saves a great deal of time. These operations have to be very carefully synchronized to guard against congestion or idle time in the plant. It frequently happens that the open hearth is not ready to receive the pig-iron when the blast furnace is tapped and, in that event, the liquid is poured into a "metal mixer." This is a large non-active furnace (incapable of refining) holding several hundred tons of molten pig-iron. Such a reservoir of molten metal ensures that the open hearth furnaces are never held up for want of the necessary pig-iron.

During the "blow"

In Bessemer practice, liquid pig-iron from the blast furnaces is transferred in a ladle to a converter (a large brick-lined steel vessel) which, to receive the charge, is tilted to the horizontal position by means of a rack and pinion. After the charge has been poured from the ladle into the converter, powerful air-jets in the bottom of the converter are turned on when the vessel is moved to the vertical position and the air allowed to pass through the molten metal. The oxygen thus supplied burns out, or oxidizes, the excess carbon and other impurities. During the "blow," flames and sparks are ejected in large volume from the mouth of the converter and, seen for the first time, are a fascinating spectacle. As the carbon is eliminated, the flame drops (there being little more carbon to burn) when the converter is returned to the

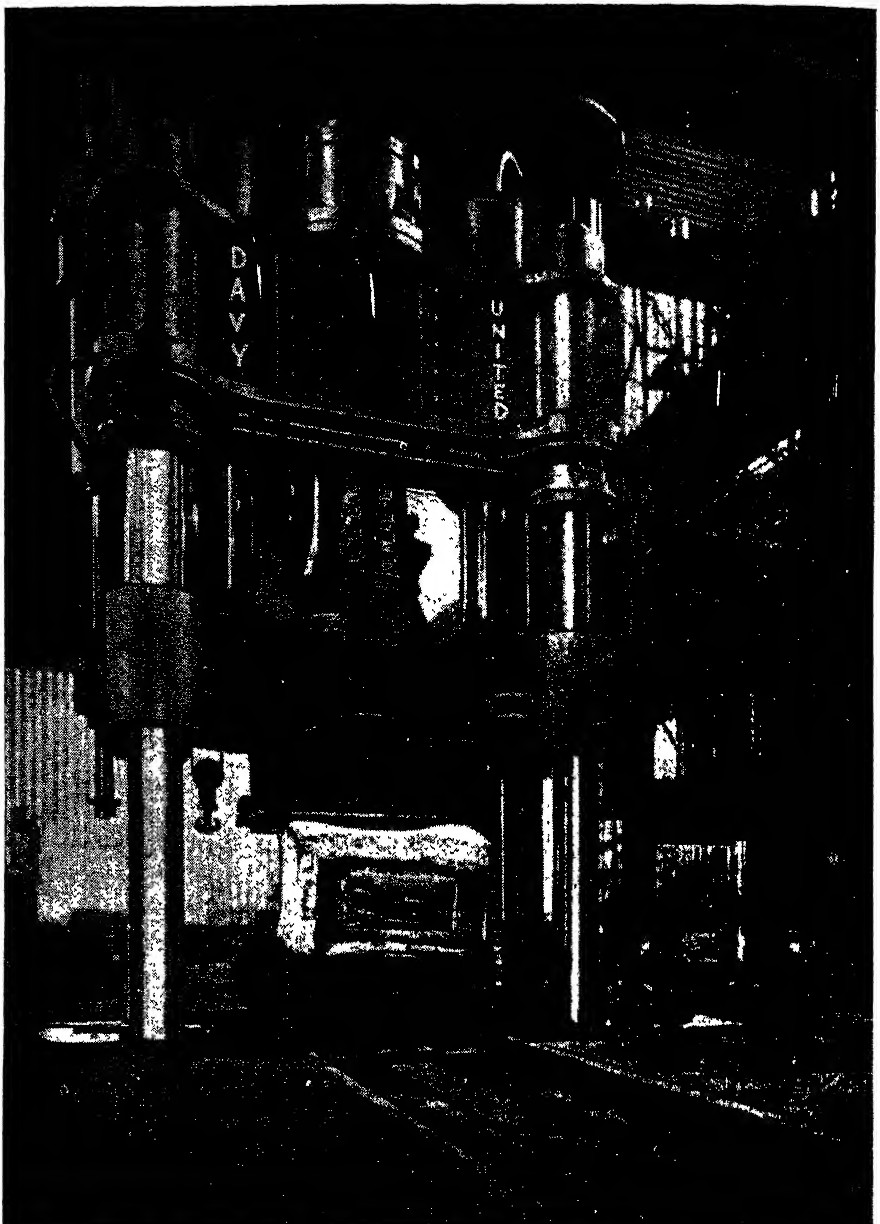


FROM MINE TO FACTORY: *How a modern steel works may be planned to ensure maximum efficiency and satisfactory working conditions is here demonstrated in a drawing of an imaginary factory, various of the buildings being diagrammatically cut away to expose the processes carried on within them. Many of these processes are illustrated on a larger scale on other pages, where their details can be studied.*



STEEL AS A VITAL LINK

Some idea of the complex relationship existing between such a steel works as this and sundry other great industries is given by the numbered items in the background of the drawing. Nos. 1 and 2 and their subsidiaries symbolize the sources by which the factory is fed with materials; Nos. 3—6 typify industries which are themselves supplied by steel works—a vital link in the chain of Britain's enterprise.



HIGH SPEED FORGING PRESS

A 6,000-ton hydraulic forging press is seen in action. The ram descends from above while the work is supported on a fixed anvil, the control gear being so designed that the movements of the press head imitate exactly those of the lever which is worked by the attendant and can be instantly arrested. Outlying edges of massive forgings are supported by an overhead crane.

horizontal position and the steel poured into a ladle. From this point onwards, practice in the open hearth plant and the Bessemer plant is similar.

From the ladle the metal is poured or "teemed" through an aperture or "stopper" in the bottom of the ladle into ingot moulds set in a pit below the level of the respective furnaces (Fig. 5). After the steel solidifies the moulds are removed leaving a mass of steel known as the ingot. This operation is appropriately called "stripping the ingot."

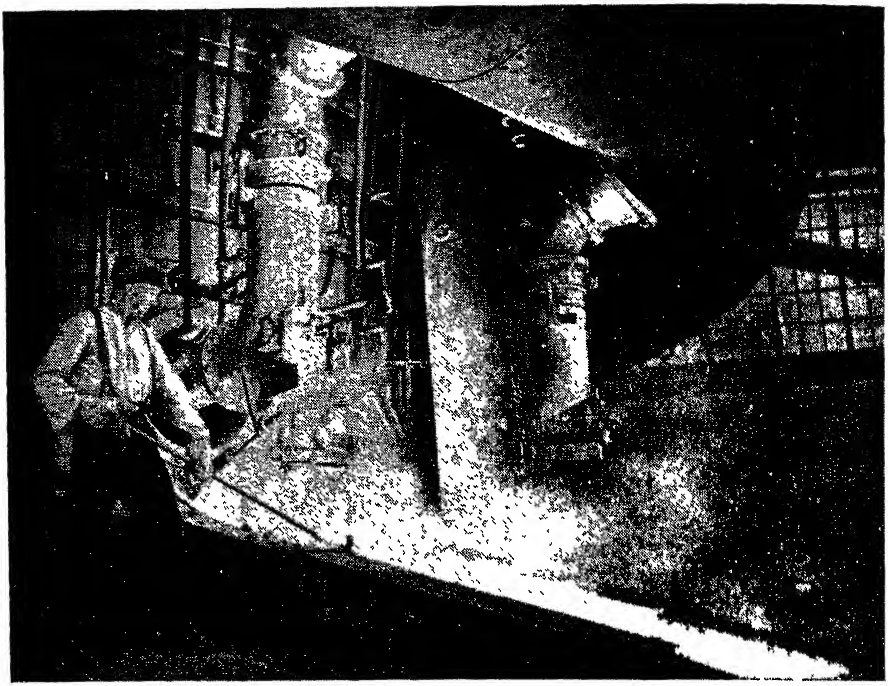
These ingots are destined to be rolled into smaller sizes called blooms, billets, bars, plates or shapes, or forged under powerful hammers to any required form. These processes require very heavy and massive units of plant, but it must not be forgotten that the steel worker is the mainspring behind them all.

RED HOT SLABS

After being rolled, red hot slabs are removed for further processing by means of electrically operated rollers ("live" rolls) located in the floor of the mill.

Before the ingot can be rolled or forged, it must be brought to a uniform high temperature. It is, therefore, transported by an overhead crane or mechanical chariot to the reheating furnaces. The process of reheating requires a great deal of skill and the men in charge, through long years of experience, can always tell the heat of an ingot within very narrow limits, merely by looking at it. It is an interesting fact that steel may be made so hot that its crystalline structure is destroyed. In that condition the steel is said to be "burnt"; it becomes brittle and unworkable and is often completely ruined. After the necessary time in the heating furnace it is removed and placed on power-driven rolls leading to the "cogging" or breaking-down mill, when it is passed forwards and backwards between huge rolls, usually operated electrically. In this mill the ingot is reduced in cross-section with a consequent increase in its length, for the total volume remains the same. This operation is continued until the required size has been obtained. The elongated ingot is now known as a "bloom" which, while still hot, is sent to shears adjacent to the mill and cut into lengths.

In electric furnaces the heat necessary to melt the charge is supplied by an electric arc, or in smaller furnaces, by induction. After the steel is melted and refined it is tapped into a ladle, usually by tilting the furnace. From this point the



RECLAIMING SCRAP METAL

A steel worker is seen tapping a blast furnace in one of the largest scrap-iron yards in Great Britain. There are sixteen different kinds of scrap iron and its methodical collection and melting down provide a valuable economy in time of national emergency.

procedure is the same, as in the case of the open hearth and Bessemer steels.

Liquid steel, of course, may be required in a steel foundry for the manufacture of steel castings. Here the procedure is roughly similar to that previously outlined for the iron foundry, requiring the same highly skilful operations of pattern-making, moulding, dressing, fettling and cleaning.

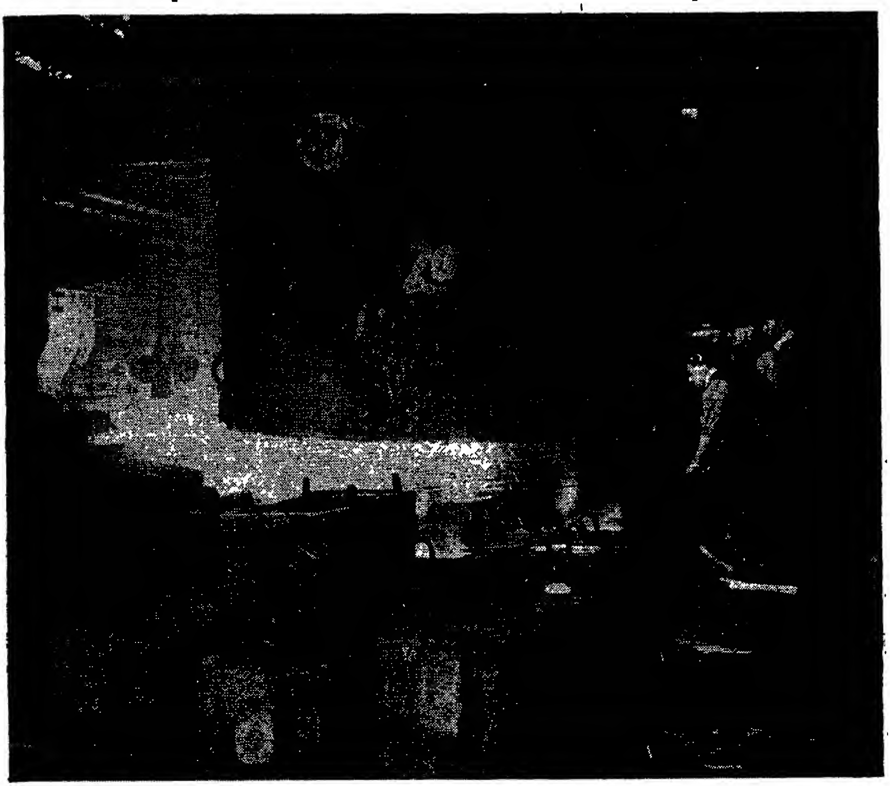
The most common variety of steel is mild carbon steel, used in ship-building, boiler making, for constructional purposes and many other uses. These steels contain about 0.2 per cent. of carbon, 0.5 per cent. manganese, and about 0.2 per cent. of silicon with some sulphur and phosphorous as incidental impurities; the balance is iron. Within limits the hardness of a carbon steel depends upon the carbon content, and when harder material is required it is only necessary to raise the percentage of carbon which can be done during the refining period in the melting furnace. The hardness of carbon steel may also be increased by heating to a red heat and quenching in water or oil, or other medium. This is known as "heat treatment," and is required by most alloy steels.

Alloy steels

A term in common use in the industry is "alloy" or special steels. These are carbon steels plus one or more metals which have been intentionally added to give some additional properties such as increased toughness, hardness, resistance to heat, shock and wear, ease of machining, and resistance to corrosion by chemicals, seawater, or polluted atmospheres. The alloys mostly employed are

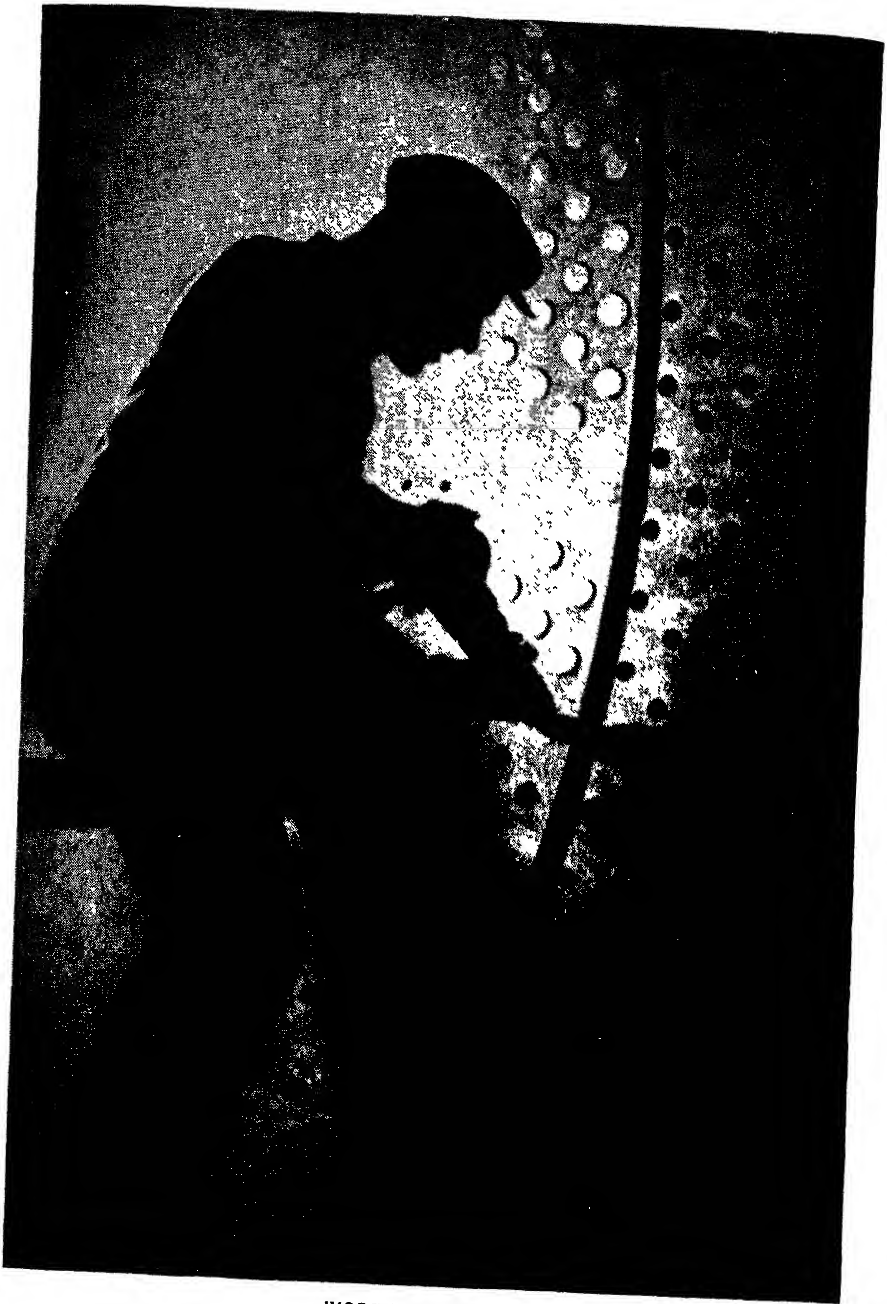
nickel, chromium, vanadium, molybdenum, cobalt, tungsten, aluminium, copper, manganese, lead and sulphur.

After it has passed through so many processes, one has still to ensure that the material is fit for its intended purpose and at this stage many different kinds of tests are made, the nature of which depends entirely on how the material is to be used. The most common is the tensile test where a bar of known dimensions—usually prepared to a standard size—is inserted in a tensile-testing machine and pulled or elongated until it breaks. The load at which the bar finally fractures is noted, and a simple calculation is made to find the "tons per square inch" which is the figure used by engineers in designing a structure. Bend tests are sometimes taken on standard bars to find at what angle the material will fracture. Chemical tests are also made and often, particularly with alloy steels, sections of material are prepared for examination under the metallurgical microscope. Important material may also be submitted to X-ray tests. Should all the appropriate tests to which the material has been submitted satisfy requirements, inspectors examine the material for size and surface condition and if these are satisfactory the finished steel is released for despatch.



DRAWING A SAMPLE

During the "teeming" (seen on page 58), a worker withdraws a sample of molten metal by means of a long iron spoon. Rapid analysis of such samples reveals the exact state of the metal, thus tending to eliminate any unwanted variations in quality which might affect the job in hand.



WORKER IN STEEL

Riveters play a vital part in the construction of many of the miracles of modern engineering, for any faulty work on their part would mean flaws that would mar the efficiency of the finished job. Above is shown a riveter hard at work in one of the great production centres of Great Britain.

WORKERS IN IRON AND STEEL

By H. C. Town

Men behind the machines. How factories are planned to ensure a level flow of production. Toolmaking, casting and machining. Types of machine tools and what they do. Guarding the worker against accident. Methods of ensuring absolute accuracy. Importance of maintenance and repair work. Inspecting the finished job.

Though Mr. Smith has an up-to-date mind, he sometimes reverts to old-fashioned metaphors. In his more rhetorical moments he may even assert that the "iron has entered his soul," or that one of his heroes is as "true as tempered steel," without pausing to reflect that such time-honoured fancies have gained a new lease of life. Wherever Mr. Smith goes—and Mrs. Smith too—are things made of iron and steel.

Certain districts have tended to monopolize definite branches of the industry, thus producing artisans whose skill is handed down from father to son. Sheffield for steel workers, Yorkshire and Lancashire for machine tools, Coventry for motor cars and cycles are instances, while Birmingham is a big centre for general engineering. Shipbuilding centres on the Clyde, Tyne and Mersey are, of course, world-renowned.

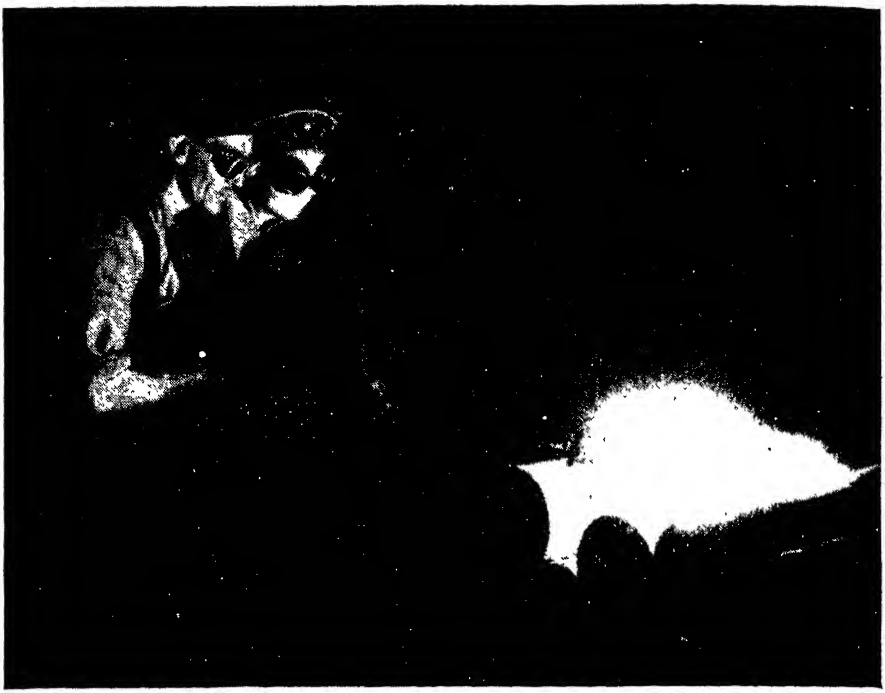
Manufacturing cannot proceed without basic design, so the staffing of a drawing or design office will be considered first. The chief draughtsman is responsible for all design, upon which the success or failure of the firm may depend.

The members of the drawing office staff include the leading designers, or section leaders in a large office, who plan out the designs and allocate them to the junior draughtsman to draw out the detail parts. While the designer requires creative, inventive, and mathematical ability, the junior draughtsman requires the experience to visualize the parts of a machine from a complicated drawing.

Adjacent to the main office are copying, printing or photographic rooms. Here the finished drawings or tracings are copied, either on blue-printing machines or by other processes which enable a supply of prints to be sent to the workshops.

In order that unskilled labour may be employed in the machine shops, and to save valuable manufacturing time, jigs, fixtures and gauges are employed to a considerable extent. The first two may be briefly described as devices for holding the work and guiding the tools, so that the operator's work consists largely of stopping and starting a machine, and replacing a finished part by another casting or forging. Gauges are measuring instruments which enable the checking of finished parts, often by unskilled labour. While simplifying the work, these aids to production, many of which will be seen later, require the utmost skill in manufacture and a wide workshop experience from those designing them. The jig and tool drawing office may be attached to the main design office, but is often a separate department or attached to the tool-room.

The work of the tool-room staff is to produce the cutting tools used on the machine tools. These latter are the power



DESCALING GUN BARRELS

How men and women—in this case husband and wife—work side by side in a great steel works is well exemplified in the above illustration, where the man, a burner, is showing the woman how to descale gun barrels by the application of intense heat. Dark goggles protect the workers' eyes.

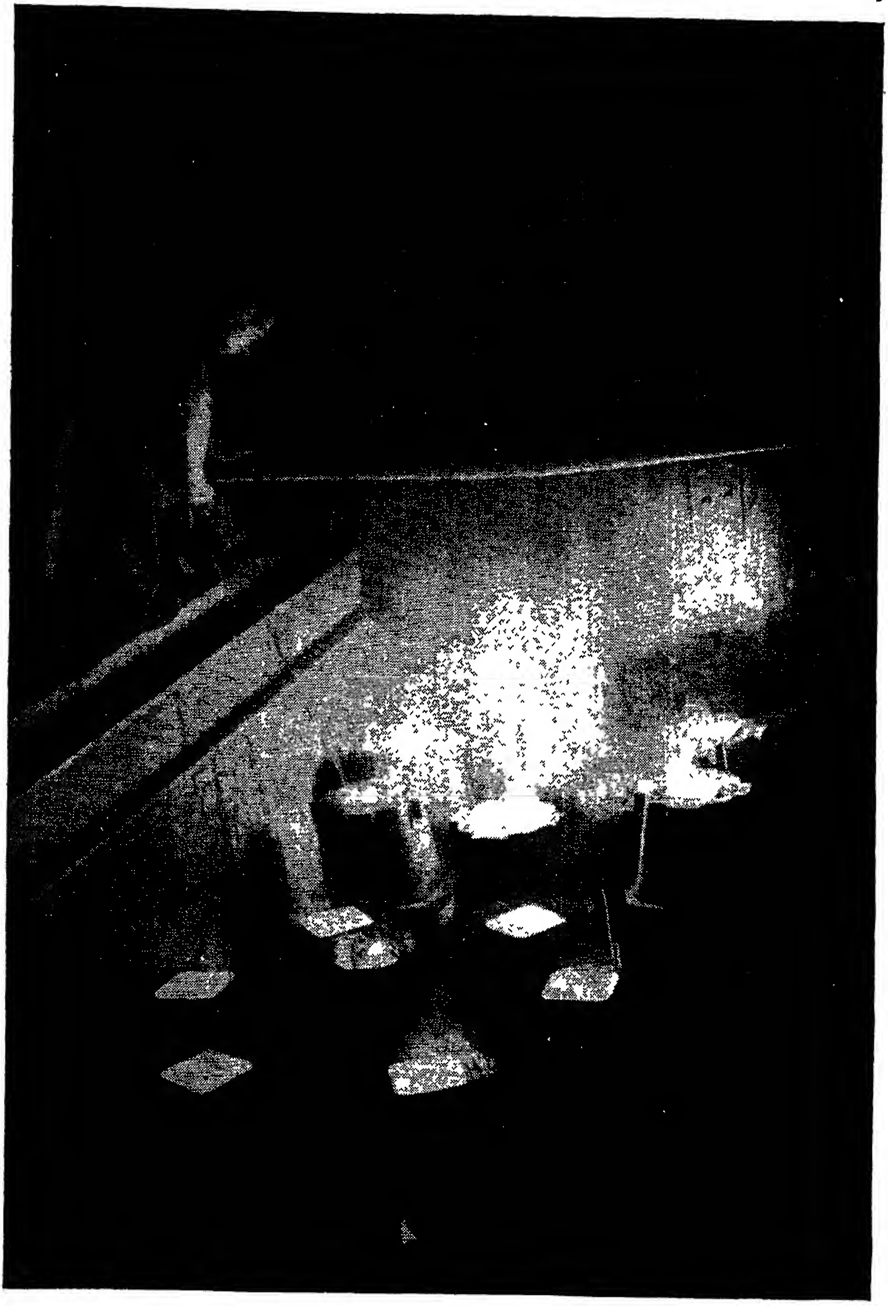
driven machines used in all machine shops, no matter what the engineering product is, and comprise mainly lathes, drilling machines, milling machines, grinding machines, planing, shaping and slotting machines, all with one common feature of producing shapes in metal by a series of repeated cuts.

To equip these machines with drills and other cutting tools of high-grade materials is an expensive item, while the manufacture of the tools demands the highest skill found in the machine or fitting shops. Thus the toolmaker requires a wide experience in the operation of many types of machine tools, or manual dexterity in the use of hand tools, coupled with the ability to obtain fine accuracy down to one 10,000th of an inch, and sometimes still finer limits, with the use of precision measuring instruments.

Planning engineers are usually promoted from those workmen or draughtsmen showing a knowledge of the capabilities of machine tools and what can be expected in a given time.

The planning engineer, then, must carefully consider each part of the product, say an engine, comprising cylinder, piston, crankshaft, valves, etc., and draw up a list of the operations in the correct sequence for each part.

Alongside the planning engineer is the ratefixer, responsible for deciding how long the workers ought to take over any particular operation and what price should be paid for doing it. Experience in machine tool operations or of assembly



FIRE AND STEEL

Calmly, skilfully, a worker tends and tests the glowing moulds filled from a mighty ladle: such ladles are actually huge containers which discharge their burden through a base vent.

times is a necessary qualification; or rates may be calculated by comparison with previous jobs, data of which accumulate; and in some cases, times are obtained by performing the operation in several ways.

If we were to look inside a factory making war material, tanks or wagons in large quantities, we should find the "line system." Alongside the machines would be moving belts or conveyors carrying the various parts from machine to machine, until each part is completed. We should see iron castings and bar steel brought to the factory and moving through the departments to the delivery door as finished machines or parts. This method of manufacture finds its main application in automobile factories and similar mass production shops. In such a factory a unit, say a cylinder block, may pass successively to a wide assortment of machines, such as milling (Figs. 2 and 3), drilling, boring and tapping machines, all being mounted side by side so that the distance the work travels is reduced to a minimum. Finally all units converge to a common assembly line.

"Group system"

With heavy engineering products, or where a firm makes a wide range of products, this system is not feasible, so the "group system" is employed. The works now comprise various departments, turning, milling, drilling, planing, shaping, grinding, gear-cutting, etc., depending upon the work carried out. But the principle is the same in all works, in that all the lathes, all the drilling machines, etc., are grouped together.

With either system it is necessary that someone should be responsible for the work to move through the factory at a definite rate. Otherwise much idle time will result if work is not available, or alternatively congestion around the machine will take place if castings or steel parts arrive in larger quantities than those of the finished product leaving the works. This balancing of the work in every department is the job of that responsible official, the progress engineer.

Before any part can be made in cast iron, a wooden pattern has to be made. Many intricate problems arise in pattern-making, so that besides having skill in the use of woodworking tools, the pattern-maker requires a knowledge of complicated engineering drawings and foundry procedure. Otherwise he may find that the pattern fails to produce the casting required. The foundry personnel will include a manager, foreman, moulders and core-makers, with some semi-skilled labour operating moulding machines.

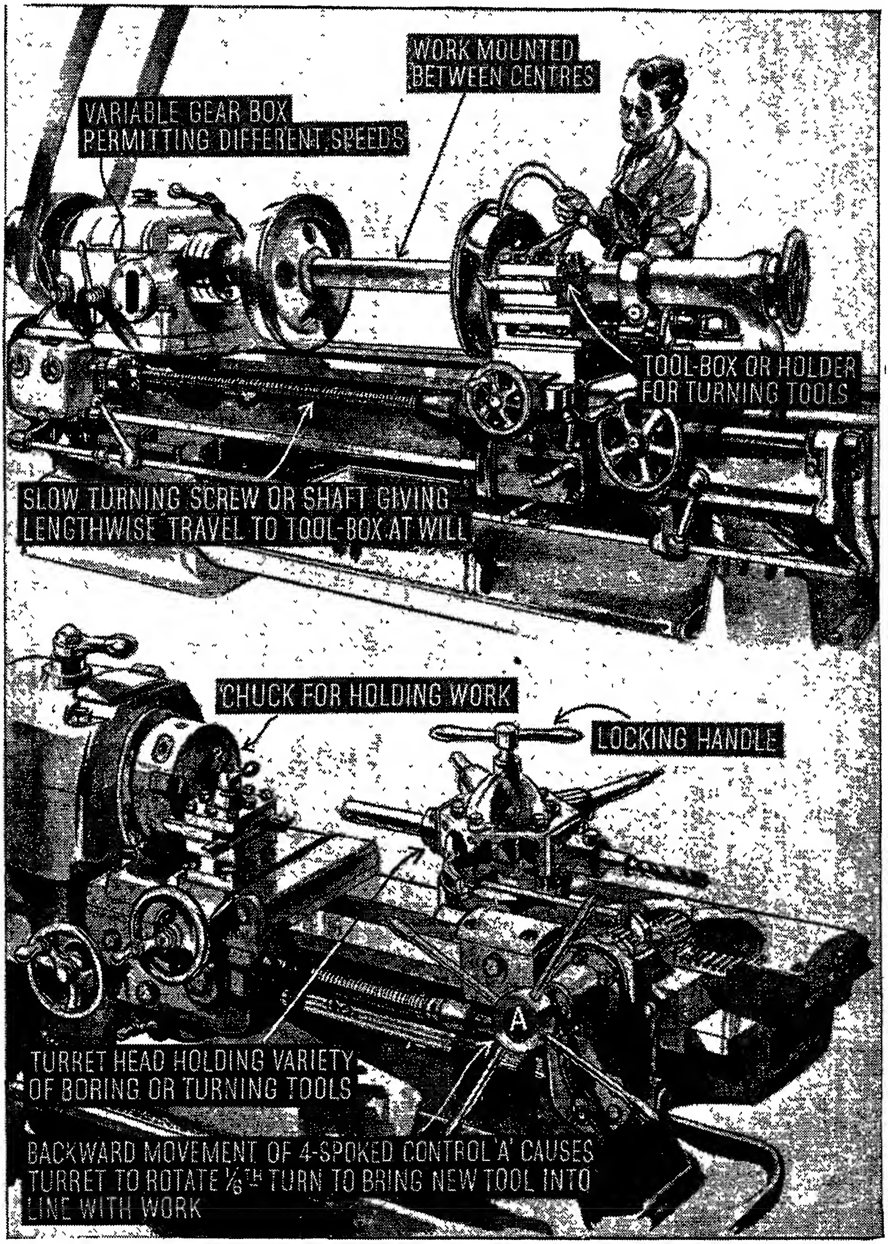
How work is divided

The method of producing simple iron castings can be seen on page 52; but some castings require many tons of metal so that the molten iron is run off into large ladles, and crane-conveyed for pouring.

The flow of castings from the foundry and the arrival of bar steel enable the machine shops to commence production. Distribution of material is generally left to the foreman who arranges it so that each machine has sufficient work in front of it for a given period of time.

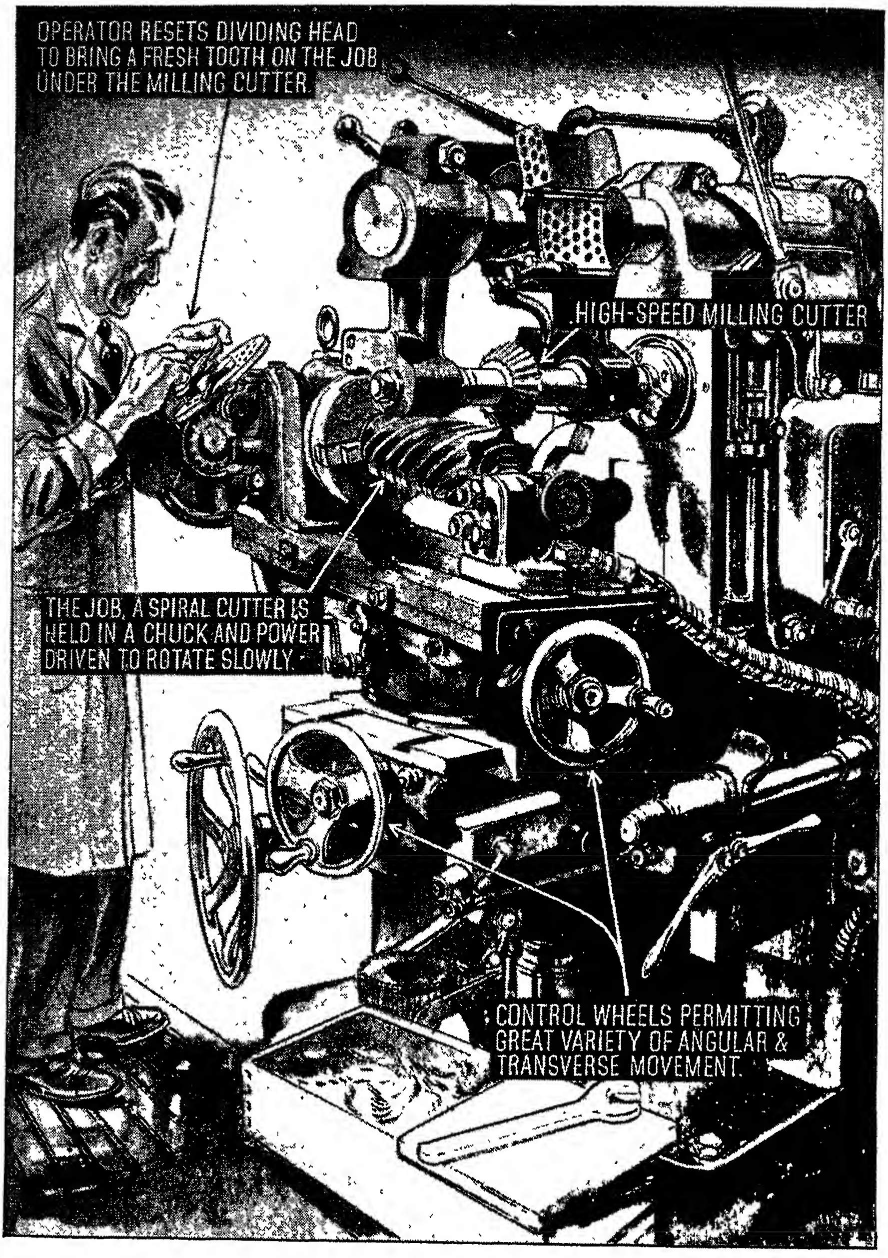
The general usage of machine tools is to produce cylindrical surfaces on lathes of several types, and on grinding machines. Holes are drilled and bored on many types of drilling and boring machines, while planing, shaping and milling machines are used to obtain flat surfaces. Various degrees of skill are required for working these machines, so that machine shops comprise apprentices and skilled men, semi-skilled and unskilled labour.

A turner's work is that of a tradesman who has served a period of apprenticeship. He is expected to operate many kinds of lathes, to produce a wide variety of cylindrical parts and to cut screws of all types. His chief machine is the centre



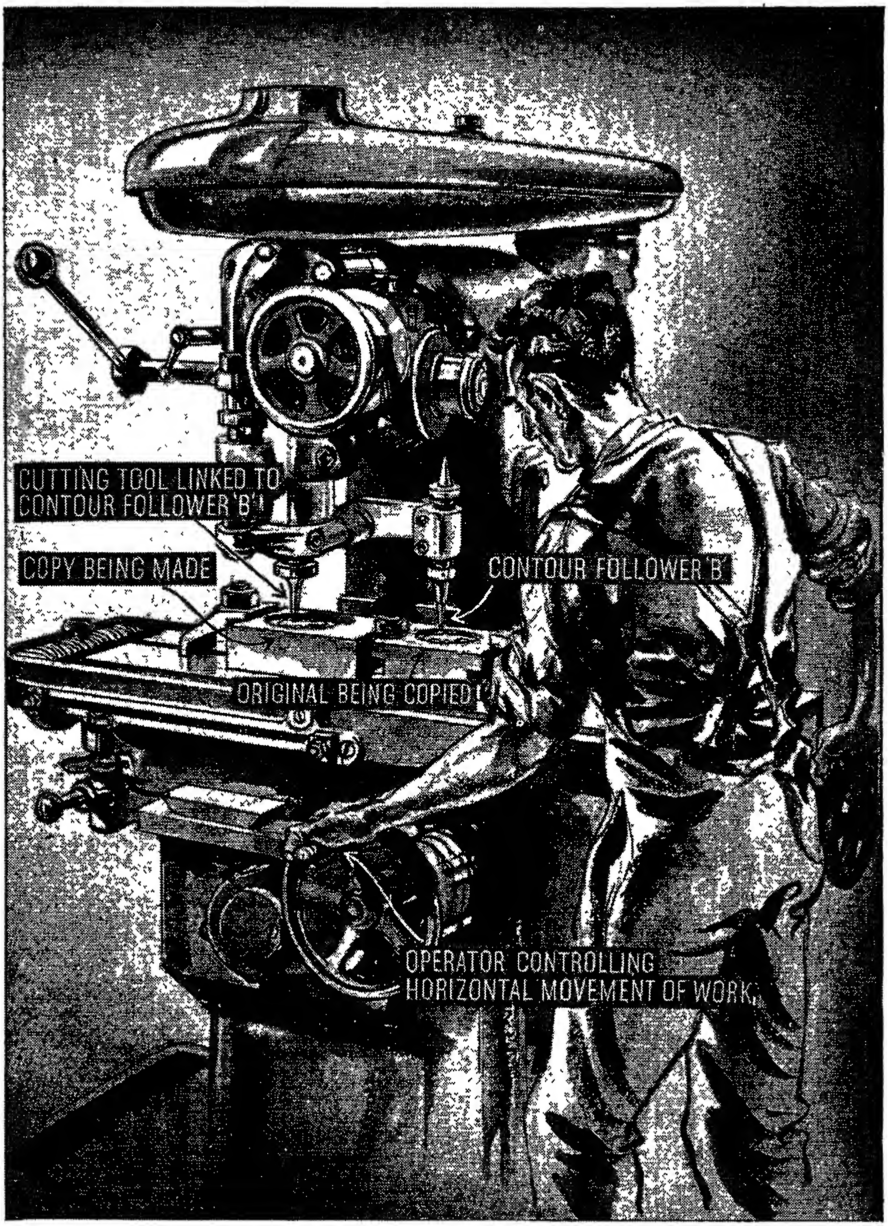
CENTRE LATHE AND TURRET LATHE

FIG. 1. *Above is shown a centre lathe, which is the most widely used of all types of machine tools. Its operation calls for a high degree of skill and the ability to measure with precision tools. Below: a turret lathe. Here the multiple tooling enables several operations to be performed in succession from one setting of the work, and ensures high production on repetition-work pieces.*



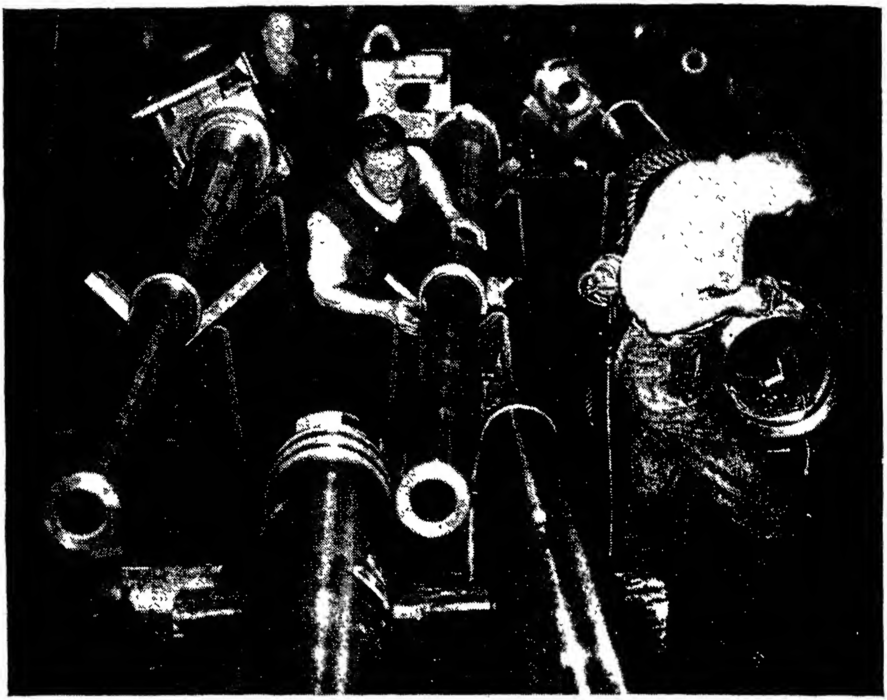
UNIVERSAL MILLING MACHINE

FIG. 2. *The principal features of this widely-used machine are illustrated in the above drawing. Here the machine is depicted cutting spiral grooves in the job. This is divided for each groove and the milling cutter then travels along as the job being machined is slowly revolved. By such means, not only is a high degree of accuracy attained, but actual production is speeded-up.*



VERTICAL MILLING MACHINE

FIG. 3. *Another of the many wonderful mechanisms used by our workers, a vertical milling machine is shown above, engaged in producing an intricate shape. The operator keeps a pointer or contour follower in constant contact with an approved copy of the finished article, its movement being accurately reproduced by the milling cutter on the job that is shown being machined.*



BIRTH OF A GUN BARREL

Many and varied are the processes involved in producing a gun at an ordnance factory. In an earlier illustration, gun barrels were being descaled by the application of heat. Here fitters are seen plying their skill on gun barrels that have already been turned and bored.

lathe which is the most universal machine tool and is to be found in all engineering workshops and tool-rooms. Spindles and shafts made on centre lathes are left larger than the finished size to allow for grinding, but much turning and lathe boring requires great accuracy (Fig. 1).

Task of the tool-setter

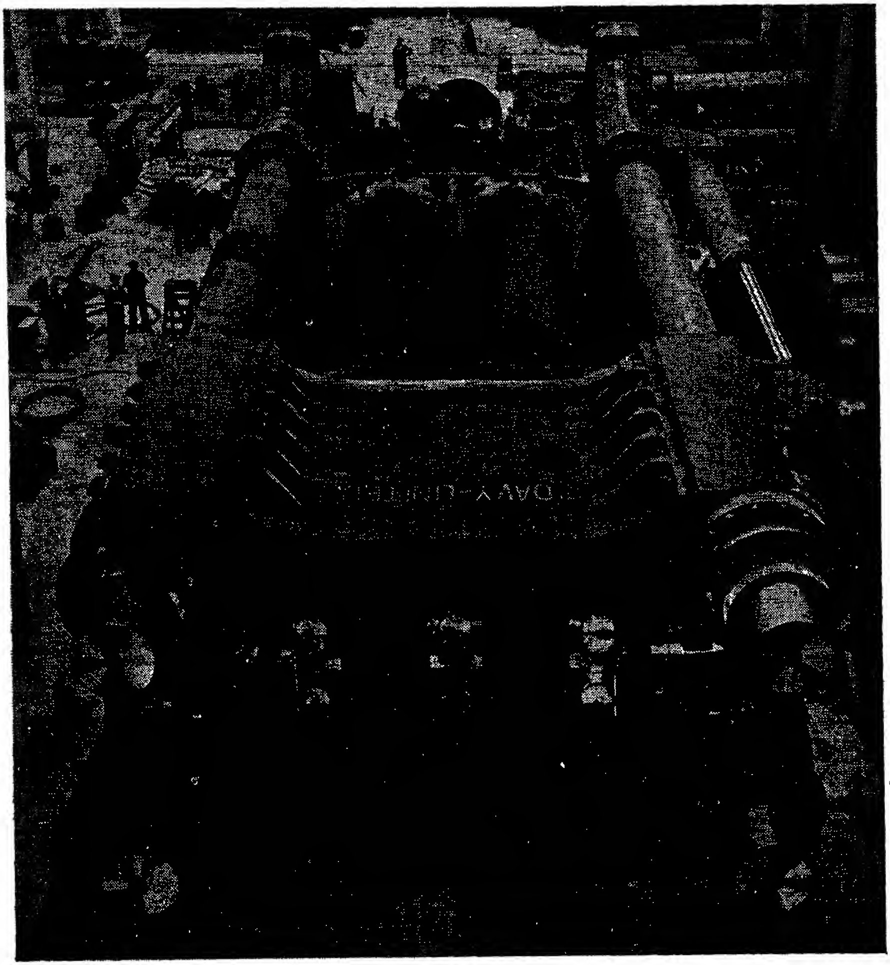
Capstan and turret-lathes are similar in type, but differ from the general turner's lathe in that they are used for mass production purposes. Many cutting tools are mounted in turrets, ready for swivelling round to take a cut in turn (Fig. 1).

The fact that cutting tools and drills are always in the correct position, without changing for each operation as with a centre lathe, results in a considerable reduction of the skill required to produce the finished work, so that women and semi-skilled workers can be employed. The main skill consists in setting up the tools to give the correct size, and this is the duty of the tool-setter, who may be responsible for maintaining a group of machines in working order. An alternative to the turret-lathe is the automatic lathe, which, once correctly fitted with tools, requires only that the work shall be placed in position and taken out when the machine stops. In the factory these machines are arranged in lines, say for small shell making. One worker in this case will attend to several machines. A tool-setter or inspector checks the work at intervals.

In view of the great influx of workers

new to factory life, the safety factor assumes a new importance. Workers are protected by factory acts which compel the guarding of all dangerous parts of machines, but the human element is often at fault, so that safety guards are found discarded, while dangerous clothing is worn against all instructions. Lack of attention, carelessness in leaving things on the floor, and cleaning or oiling machines in motion may also result in accidents. Damage to the hands is the most prevalent. When all precautions are taken, it is rarely feasible to protect a tool at the actual cutting point.

A good operator's pride is the care of machine and equipment. A modern machine tool and its equipment may represent an investment of approximately £1,000, and if idle is a direct loss to pro-

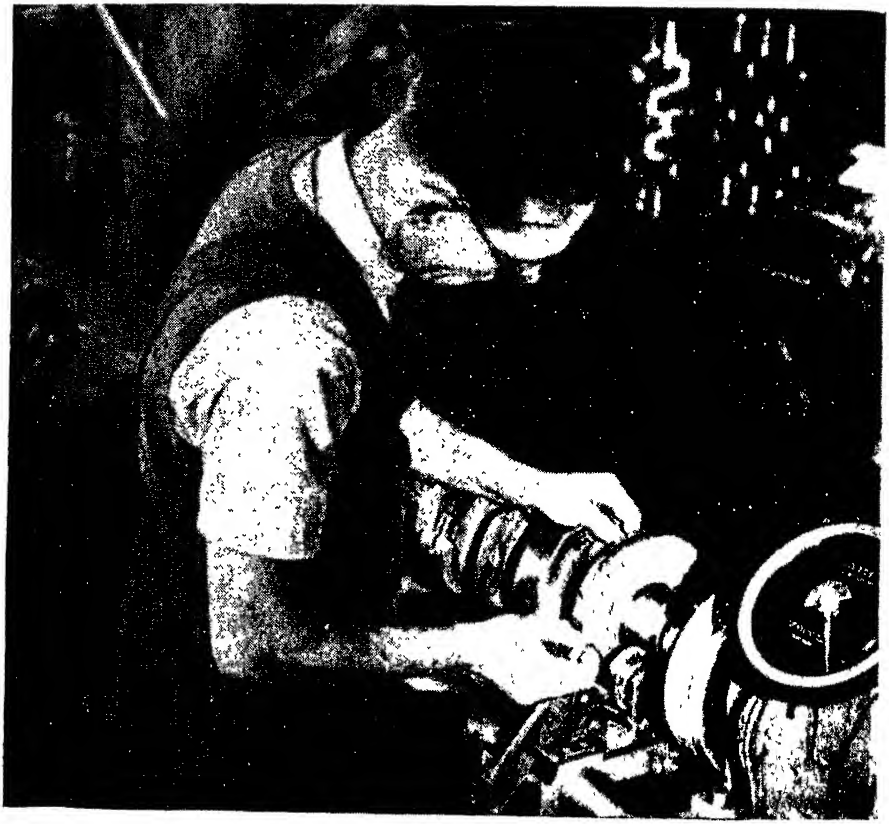


MAJESTY OF THE MACHINE

Some idea of the enormous size and power of this 15,000-ton armour plate bending press is obtained when one contrasts it with the figures of workers standing beside and behind it. In the grip of the press can be seen a great piece of plating which is in process of being shaped.

duction. Upon the accuracy of the machine depends the quality of work produced. It is maintained by keeping the machine clean, oiling it regularly and protecting the sliding parts from being damaged by the dropping of hammers, spanners or heavy work. Particularly important is the matter of oiling and a good operator will see that all oil holes are kept free from being clogged with dirt.

Production of accurate holes forms a large part of machine minding, the main operations being drilling and boring. The first-named is the process of cutting holes in solid metal, whereas boring is the enlarging of holes already left in the rough casting. If jigs are available, then drilling becomes a very simple repetitive operation, suitable for unskilled or semi-skilled workers. Their only duty is to place the work in the jig, which ensures that the holes are drilled in the right position and are of the correct size, and then to remove the work. Boring entails more responsibility, for the work may be large so that inaccuracy would result in the scrapping of an expensive casting; and older or more experienced men are usually promoted from drillers to the rank of horizontal borers.



TESTING A CRANKSHAFT

Perfect balance of revolving parts is necessitated by the enormous speeds at which modern engines run. Here a tester is running an engine crankshaft and checking any "out of balance." To correct this, it may be necessary to drill holes to lighten a part, or add weights elsewhere.

The production of flat surfaces may be by milling, planing or shaping. Many milling operations require considerable skill and experience, and these are generally carried out by tradesmen in the tool-room, using universal machines.

When the machines are equipped with fixtures for work-holding, and repetition work is available, unskilled labour, men or women, can produce milling work to satisfaction. By this process rotating cutters machine the work as it travels along, whereas planing and shaping machines use single point tools. For the first mentioned, the work travels against the tool, while for shaping, the tool moves over the stationary work. In general, owing to the size and importance of the work, planing machines require skilled operatives, whereas much shaping can be done by trainee labour under supervision—which brings us to the use of semi-skilled workers.

Use of semi-skilled labour

Where great accuracy is required, both flat and cylindrical surfaces of engineering products are finished by grinding, using abrasive wheels to remove small amounts of metal. The tendency is to produce machines with devices which remove from the operator to the machine much of the responsibility for obtaining size. Thus semi-skilled workpeople are employed where batches of similar work are available, and under war conditions with practically unlimited mass production all types of machine tools have been operated by semi- or even unskilled labour. This course, however, necessitates a considerably larger amount of supervision than under normal conditions, and also requires a great increase in skilled toolmakers to produce jigs and fixtures so that unskilled labour may be used.

A fitter's job may include preparing work for the machinist and then correcting or completing it for building into a machine. Fitters rank as skilled craftsmen after serving an apprenticeship in which they acquire dexterity in making flat surfaces by hand tools such as chipping chisels, files and scrapers. They also require the ability to read engineering drawings so that they can assemble complicated mechanisms, and are generally called upon to do a certain amount of running and testing a completed machine or engine. Fitters are responsible folk.

Marking up the job

Before castings or forgings can be machined to shape, the finished outline must be scribed upon the work or the position of holes marked for drilling. This important duty belongs to the fitter who requires a set of tools adapted for the purpose. Assuming that the finished work is to be made from the block, the workman first covers the surface with whiting or, if it is a polished steel surface, with copper sulphate, to lessen the brightness. He then carefully measures the various distances required, marks the extreme positions with a dot from a centre punch and scribes the lines to the shape shown. As there is always a possibility of the lines being erased before the machining is completed, further dots are made all along the lines.

The marker out uses a handy tool called the surface gauge (Fig. 4), by means of which he can scribe lines at various heights and in practically any position. If still greater precision be required, he has the alternative of a vernier height gauge, which enables him to locate centres or projections from a ›y plane surface (Fig. 4).

So that units may fit together, accuracy is essential. For example, if the fitter is to assemble parts without a great amount of correction, there must be some guarantee that careful checking has been carried out in the machine shops. So that customers can order spare parts with the certainty

that they will exactly replace a broken or worn part, no deviation in size must take place no matter how many parts are made. Absolute accuracy cannot be obtained, but the extent of error can be controlled, and this control is ensured by means of a gauge. There are a vast number of gauge types, but plug and gap gauges are the commonest (Fig. 4).

Inspecting the finished job

The plug gauge is for testing holes, and comprises two ends, one of which must enter the hole, while the opposite end, made a few thousandths, or even ten thousandths of an inch larger, must not. The difference between the sizes of the two ends is known as the "tolerance." The gap gauge is used in the same way, but in this case for checking the diameter of round bars or other external parts. No experience in measurement is required to use these gauges, and new recruits to the industry quickly adapt themselves to checking batches of workpieces.

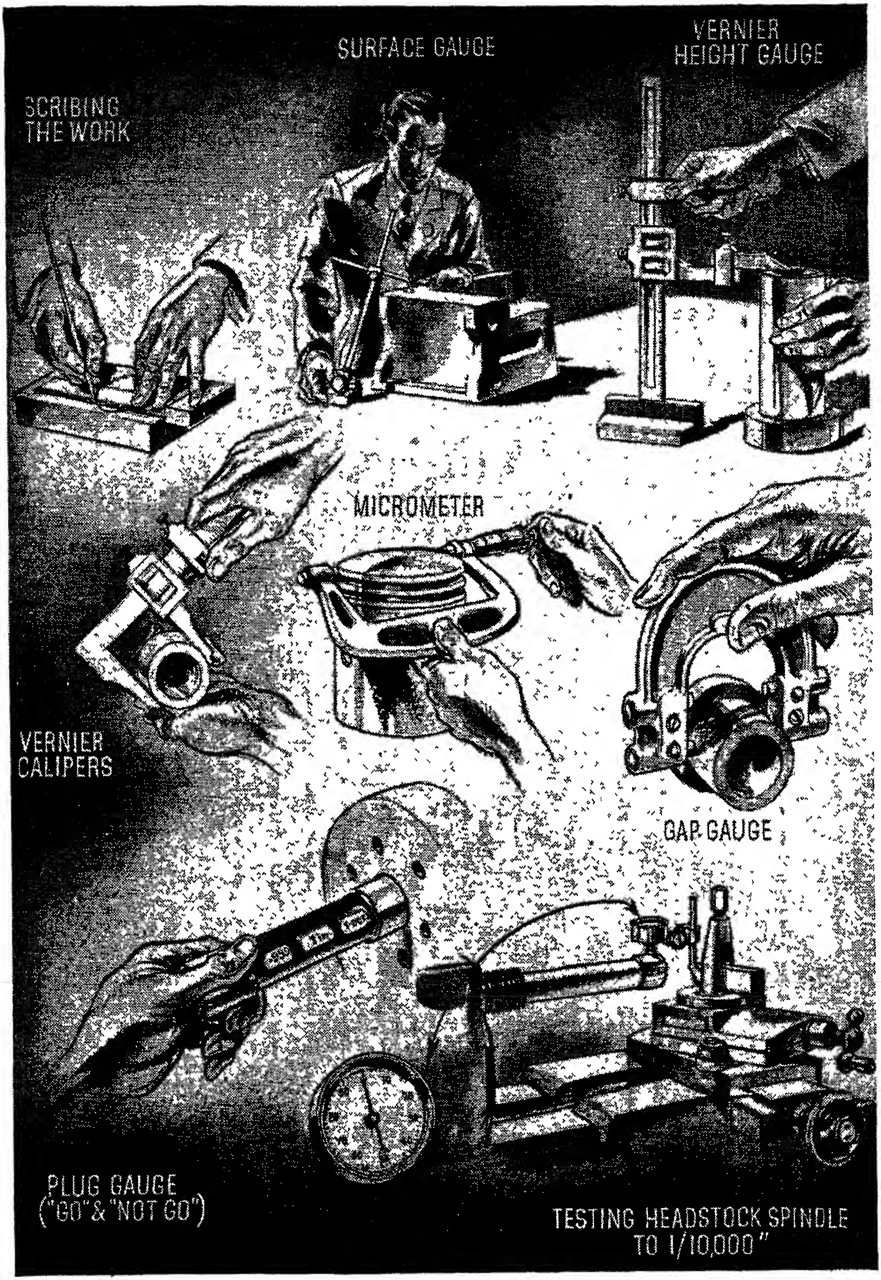
On the other hand, inspection may involve the use of many high-grade measuring instruments, optical, electrical or mechanical, while some knowledge of trigonometry is useful for checking angles. The duties of an inspector thus involve responsibility for passing or rejecting not only small units, but perhaps a complete machine or engine. Recruitment is generally from tradesmen of marked intelligence who have shown technical ability during apprenticeship or in later training. All engineers should obtain proficiency in the use of measuring with micrometers or verniers, but to an inspector they are an absolutely essential part of his equipment.

Fig. 4 shows a micrometer calliper, measurement being taken between a fixed end and a moveable spindle. The screw on the spindle is cut with forty threads to each inch, or 1/40th inch pitch, so that this is the distance the spindle moves for one turn. As the spindle itself is divided around into twenty-five divisions, it follows that if the spindle is given 1/25th of a turn, it will move forward by the screw on it 1/25th × 1/40th = 1/1,000th of an inch.

An alternative instrument is the vernier calliper (Fig. 4), which, by means of the difference between two scales, will also allow readings to 1/1,000th of an inch. An advantageous feature is that internal as well as external measurements can be taken by the same instrument. Another useful instrument for the inspector is the dial gauge, which, by means of a pointer on a clock face, will register the variations, say in the height of a piece of work, or the inaccuracy of a running spindle. Thus the inspector finds it of much assistance for the final checking of the accuracy of a machine (Fig. 4).

Maintenance work

No factory could keep going efficiently without a maintenance staff to repair breakdowns. A maintenance engineer requires to be a handy man in all aspects of engineering, for, while in a large factory some specialists may be employed, in many workshops he may be called upon to repair mechanical breakdowns, electrical defects or boiler troubles. He is often needed to work during holidays, meal times or during the night. A breakdown may be such that a large part of the factory is involved, and even to close down a section may mean that production is seriously interrupted. Normal everyday duties include the mending of driving belts, lubrication of shafting bearings and replacement of driving pulleys. The maintenance engineer has also to superintend the installation of new machines arriving at the works, to deal with the arrangement of belt or electric motor drives, and to solve the problems which arise in connection with the power-transmission—that very important matter.



HOW ACCURACY IS ENSURED

FIG. 4. *Precise to within a minute fraction of an inch, gauges such as those seen above are essential aids to the production of accurate jobs in steelworks. At top left is shown how work is scribed with the outline of the job in progress, in preparation for machining it to shape.*

FLIGHT TEST PILOT'S REPORT

To a ground engineer, a test pilot passes his comments on the performance of the aeroplane—a bomber—he has just "put through its paces" in the air. Apart from a few minor peculiarities, which will receive immediate attention and adjustment, his report on the aircraft is favourable, which virtually means "another plane ready for service with the R.A.F.!"

BEHIND THE SCENES IN OUR AIRCRAFT INDUSTRY

By F. T. MEACOCK, A.F.R.Ae.S., M.J.Inst.E.

How a new type of aircraft is evolved. Importance of specification and design. Translating plans into planes. How the prototype model is constructed. Jigs and tools. Material and personnel. Work in the machine shop. Fitting processes. What happens in the assembly lines. Ready for final inspection and test flights.

EVERYDAY acceptance slows down our knowledge of things. Mr. Smith, let us say, "knows 'planes" well enough. They are such a common sight nowadays. But because this Mr. Smith is just a spectator and not in any way technically concerned, his acceptance of aircraft tends to make him forget the immense amount of work that has to be done on them before he sees the final result. To the more fortunate, who have had the opportunity of examining any aeroplane at reasonably close quarters, some indication of the complexity of the structure will be apparent; but even this will not really give more than a vague idea of the organization and the number of people involved. To supply a broad but necessarily brief survey of the production of a modern aeroplane, from its earliest conception to the first flight, is the purpose of this chapter.

The rapid advancement of the science of flight has demanded the development of new materials, forms of construction, and methods of manufacture. Highly-powered engines and a new technique in the methods of controlling the aeroplane have been evolved. The modern counterpart of the early flying machines is a very complex structure, embracing a great number of different manufacturing processes and the use of a wide range of materials. During its construction, a considerable number of groups of technical and non-technical specialists must be employed, each responsible for some definite part. The completed aeroplane is the result of the combined technical ability and mechanical skill of these groups working in close co-operation.

Planning new bombers

For the purpose of this chapter it will be assumed that a specification has been issued by the Air Ministry for a new type of bomber for the Royal Air Force. This will have been carefully drawn up with regard to operational requirements, not only at the time when the new aeroplane will first go into service, but also in the future, since it must always be borne in mind that operational considerations can undergo rapid changes. Wherever possible, allowance must be made in the specification to ensure that the new type will be reasonably elastic in its conception so as to permit its operation under several different conditions.

Contained in the specification will be found a description of requirements for the new type from both the operational and the general design aspects. For example, the latter will include such items as the desired number and arrangement of the crew's stations, emergency exits, accessibility of seats, maintenance facilities, general equipment to be carried

and so on. In addition, requirements regarding the structural strength of the main components of the structure will be stated. Under operational requirements will be given a summary of the performance conditions that must be fulfilled, such as top speed, range, take-off run, etc. Also under this heading will be found the required armament, bomb load and operational equipment such as flares, wireless equipment, dinghies and so on. The completed document is circulated to the aircraft industry for the interested firms to study and put forward tenders.

Stages in prototype construction

Having seen how the new aeroplane originates, we can now consider in what way an imaginary but typical firm of aeroplane manufacturers will translate the specification, firstly into a design and later into actual aeroplanes. The simplest analysis will show that for the production of an aeroplane, three main divisions are necessary; design, manufacture, testing.

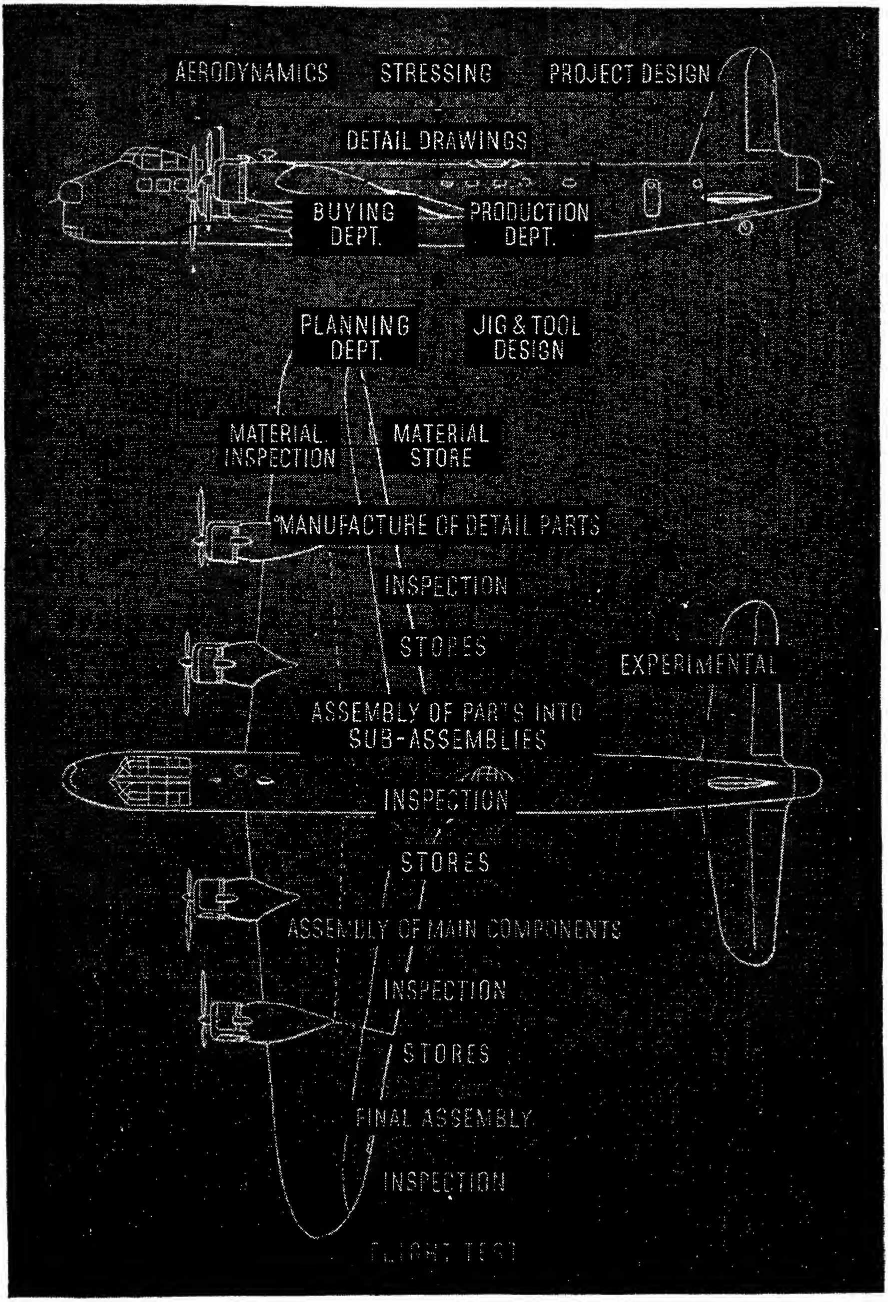
Upon receipt of the specification, the chief designer will make his suggestions and comments on the general requirements contained in it and pass it on to his design staff for more detailed examination. Generally speaking this design staff can be divided into three parts: a department dealing with aerodynamic problems, performance estimation, and weight estimation; a stress office responsible for all strength calculations; and a project office to deal with the main structural design. While these are separate and consist of groups of different technical specialists, all three departments must work in close contact. For example it is essential that the aerodynamic and stress departments be kept fully informed of any changes or proposals made by the project design office. This sub-division of the design department is then the first expansion of the "family tree," of which the final complexity is indicated in Fig. 1.

First of these departments to deal with the new specification will be the aerodynamics office. Here the performance requirements will be studied and such details as the engine's total horse power, the wing area, fuel capacity and probable size of the control surfaces will be studied. An estimate will also be made of the weight of the various main components and a preliminary layout drawing for the proposed aeroplane produced, showing the approximate position of the crew, main items of equipment, fuel tanks, bombs, etc. From this layout and the estimated weights of the various components and removable loads, the position of the centre of gravity in relation to the wings can be found. When this is completed, the department will submit to the chief designer the suggested layout together with a complete preliminary estimate of performance of the proposed aeroplane.

When the general design is agreed upon, or a modified layout is produced, the project design office will commence a more detailed design and decide the general form of the structure and the materials. In conjunction with this the stress office will make preliminary estimates of the loads carried in the main structural members, so that their approximate sizes can be determined.

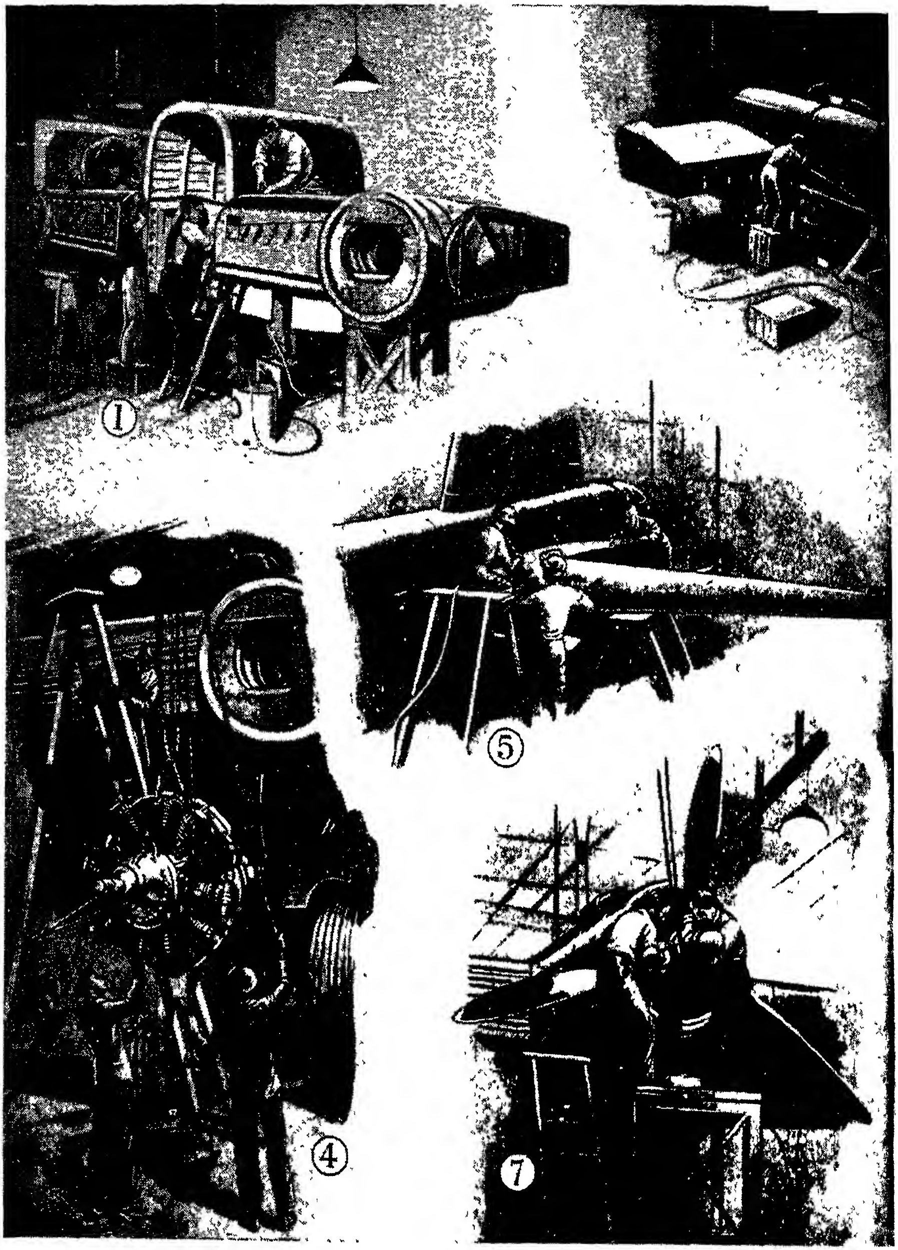
All this preliminary design work culminates in the production of a general arrangement drawing of the proposed design to fulfil the specification requirements; a drawing showing the internal arrangement, *i.e.*, position of crew, equipment, etc.; a performance summary; and a summary of the positions of the centre of gravity under various conditions of loading. These are then submitted to the Air Ministry.

If the design be approved, the Air Ministry sanctions the construction of perhaps one or two prototype aeroplanes and the firm receives an order to this

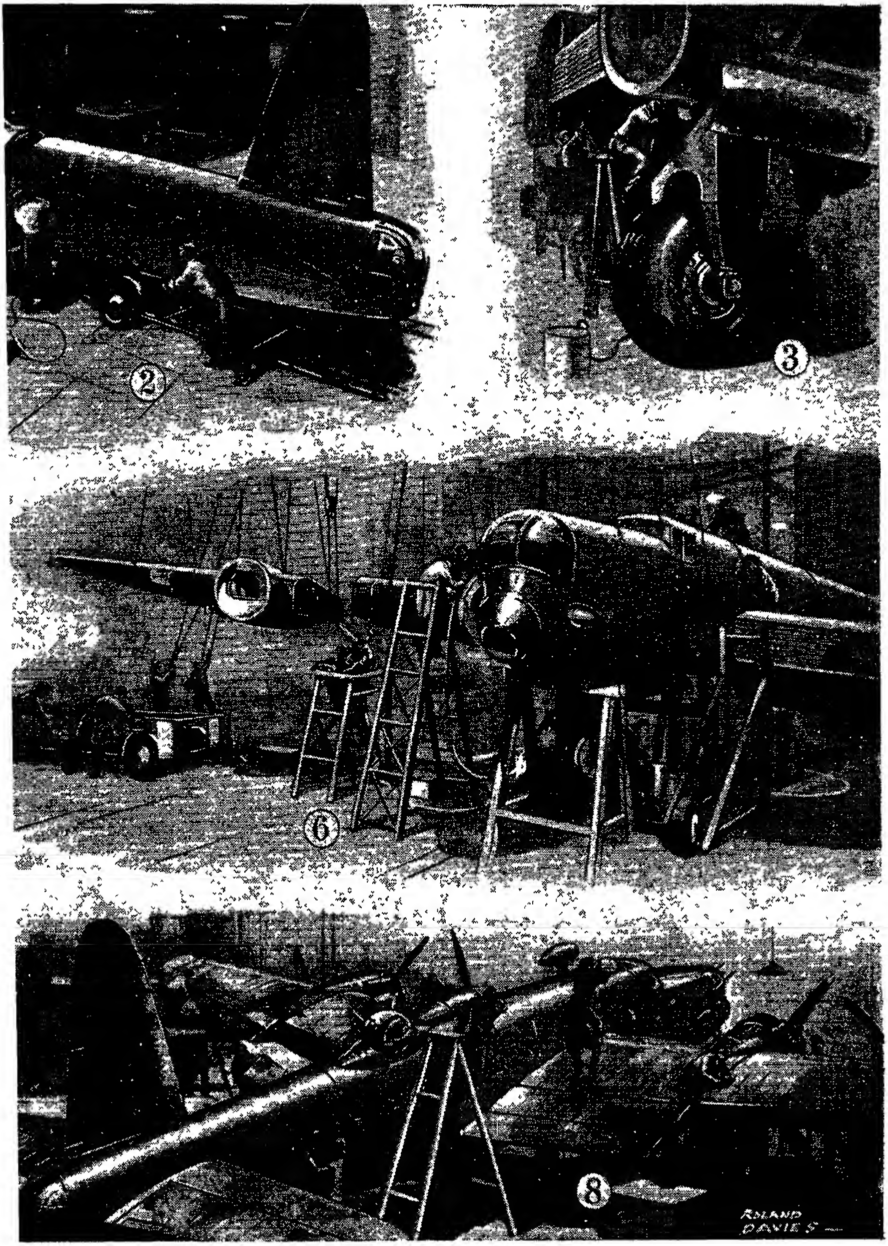


FROM DESIGN TO FLIGHT TEST

FIG. 1. *How an aeroplane comes into being and the stages of its assembly are clearly and simply shown above by means of a diagram which should be read downwards on the "family tree" principle.*



BUILDING A BOMBER:
FIG. 2. *In the above drawing is shown in broad outline the sequence of the principal processes in an aircraft factory. Time taken and methods used vary in accordance with the type of aircraft produced. The following processes are illustrated: 1, centre section assembly; 2, assembling fuselage, mid and rear portions to the centre section; 3, assembling undercarriage to centre section;*



METHODS OF ASSEMBLY

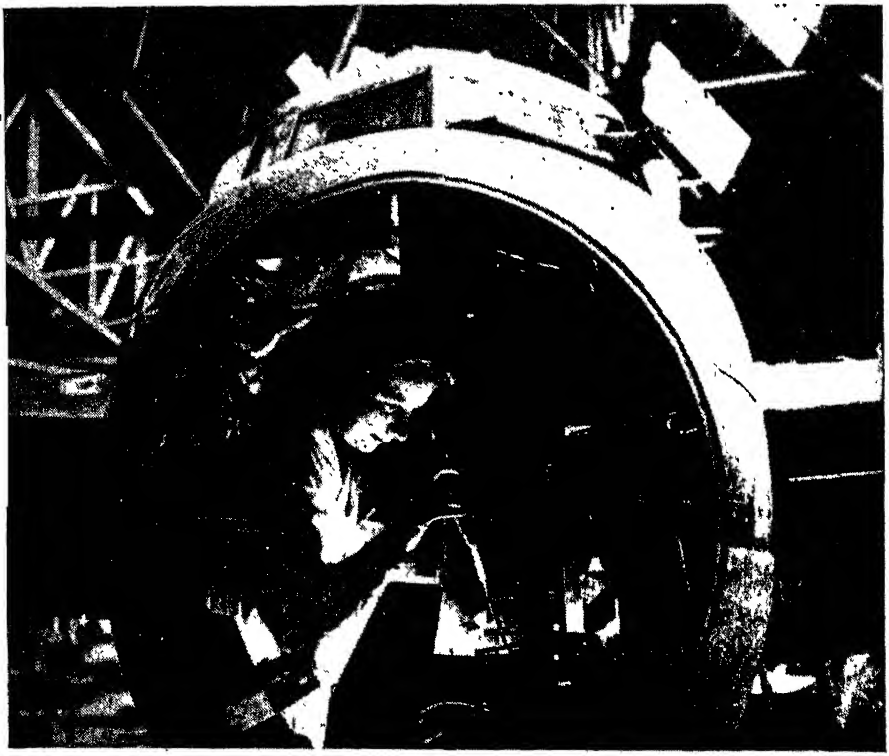
4, installing the engines; 5, assembling the tail plane to the fuselage; 6, the outer wing panels being assembled to the centre section; 7, installing the propellers; 8, the aeroplane nearing completion. By modern production methods, assembly is accomplished with a rapidity that seems almost miraculous to those who do not know the scientific care with which it is organized.

effect. As soon as this order is received, the design work can proceed to a more detailed design of the various structural components. The project office will commence to lay out the design of the members comprising the structure. While this is proceeding, more information will become available for the stress office to commence the detail calculations necessary to ensure that every member of the structure is adequate to carry the loads imposed on it during flight. Similarly the increasing detail design will allow the weight-estimating department to keep a check on their original estimates.

At this stage it is usual to construct what is known as a "mock-up." This is a full-scale model of the proposed aeroplane, or at least of the fuselage and centre portion of the wings, made from plywood and timber or commercial grade metal tubing to represent the structural members of the proposed aircraft.

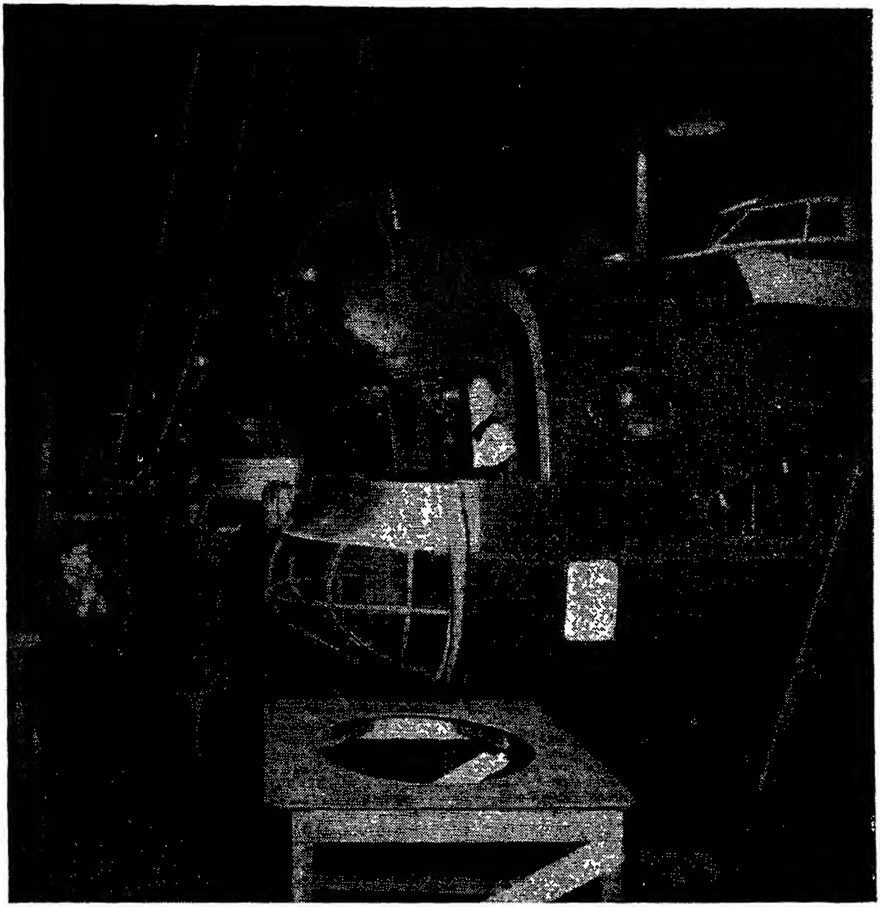
Uses of a "mock-up"

The mock-up is constructed by the experimental department, enabling the aeroplane's internal arrangement to be clearly examined. It will also provide information such as the comfort and roominess of the crew's various positions, ease of entry and exit, view from the pilot's seat, position of the controls, etc. As soon as the mock-up is completed, the



WITHIN THE FUSELAGE

One of the girl fitters in an aircraft factory is seen working inside the fuselage of one of the fast, wooden-constructed "Mosquito" bombers. This photograph gives a good idea of the complexity of the task of fitting all controls, pipelines, equipment and other accessories in the fuselage.



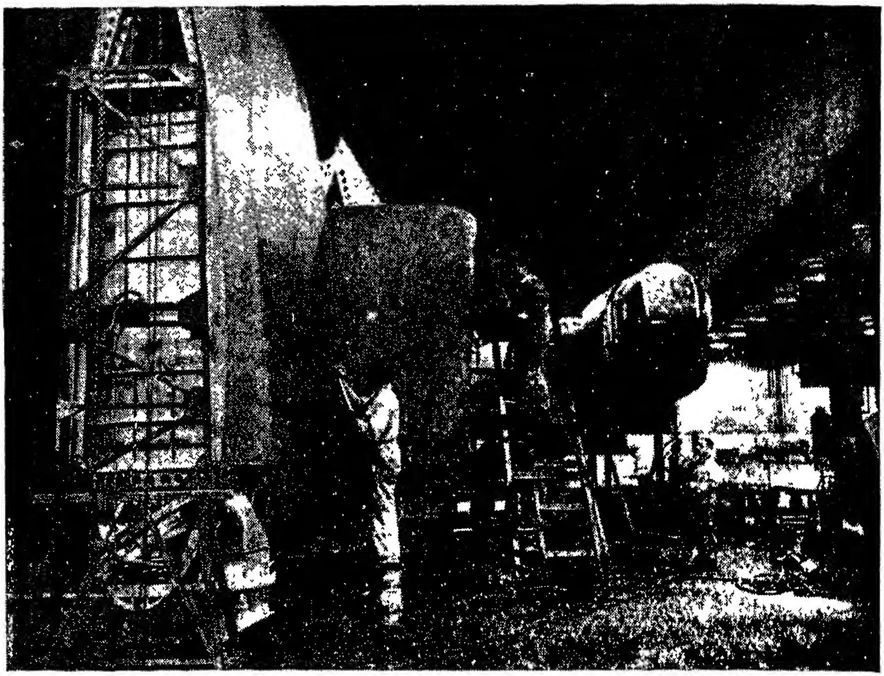
MOUNTING THE FRONT TURRET

Aircraft workers lower the power-controlled gunner's turret into the nose of a Handley Page "Halifax" four-engined bomber. Other bombers at a similar stage of construction may be seen in the background of this photograph, taken at one of the largest Ministry of Aircraft Production factories.

Air Ministry sends representatives to study the suggested internal arrangement and, if all be well, give it official approval.

As soon as possible the main layout drawings, details and assemblies are passed from the project office to the production drawing office in which drawings are made of every part of the structure, however small. A large aeroplane will need literally thousands of such drawings.

The success of any aeroplane manufactured in large quantities, depends greatly on the interchangeability of the various components. This exact degree of interchangeability can only be achieved if the parts concerned are made in jigs. These jigs are a form of tool used during manufacture and are designed by a special department known as the jig and tool design office. Thus as soon as the detail design for the various components is completed, the drawings are passed on to this department for the appropriate manufacturing jigs and any special tools



MONSTER SHAPES IN THE DOPE SHOP

FIG. 3. *A pungent odour and the ceaseless hissing of sprayers greets visitors to the dope shop, which is carefully shut away from the rest of the works to prevent fire. Above is seen the spraying of the centre plane section. Spraying serves a two-fold purpose—camouflage and preservation.*

to be designed. For the necessary shop organization a planning department is required and this will be responsible for such items as the allocation of work to the shops, shop procedure, quality and so on.

Mass production

The manufacture of the complete aeroplane can be split up into several intermediate stages, each having a separate group of people skilled in their particular form of work. These stages can be roughly classed in four main divisions. First is the construction of the detail parts from raw materials. The second stage follows when the detail parts are withdrawn from stores, into which they are placed after inspection, and built up into what are known as sub-assemblies, a number of which form the main components of the aeroplane. Building up these sub-assemblies into the main components such as complete wings, tail units and fuselages, constitutes the third stage in the process of production. Finally the last stage is reached when the main components are assembled together.

Having seen the main framework around which the constructional organization is built, let us now glance at some of the many different individual jobs that are needed.

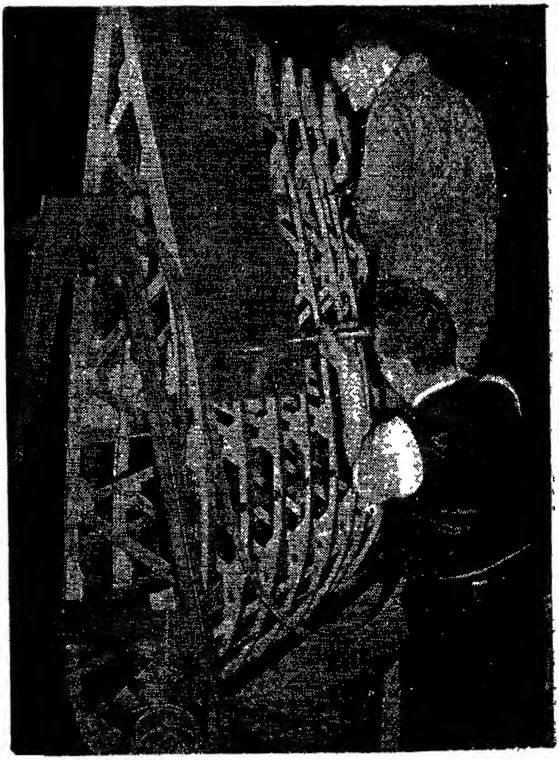
Examination of the various parts making up the complete aeroplane will show that, in general, the materials used can be divided into four main types. These can be roughly described as "solid" material, *i.e.*, blocks, bars, castings or forgings; sheet metal of two types, thick or heavy gauge and thin or light gauge;

and lastly material in the form of tubes. These of course are not all the materials used, but they give an indication of the main types of work required. Each manufacturing department or shop is under the supervision of the shop foreman who sees that the supplies of raw material or finished parts and drawings are obtained from the appropriate stores. He also sees that the work proceeds according to the planned schedule. To facilitate the supervision of the shop, the foreman has one or two assistants or charge hands.

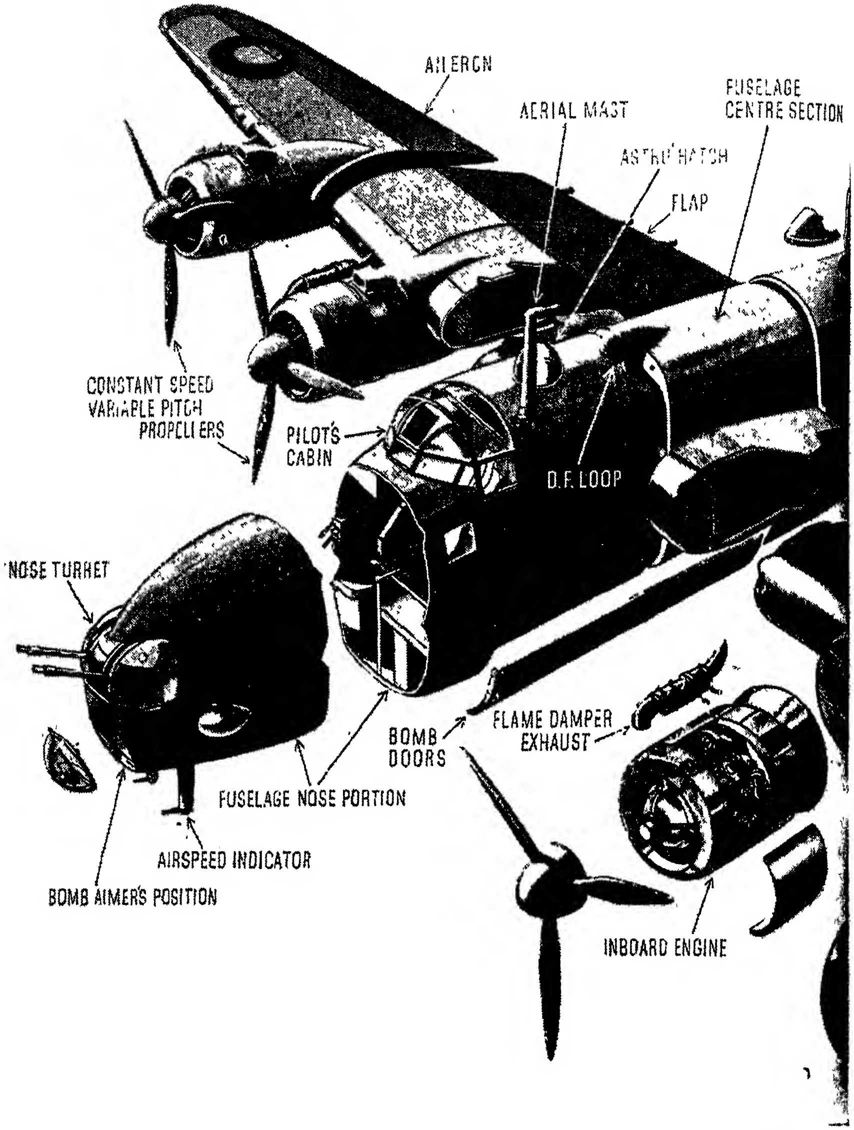
The machine shop is staffed by skilled machine operators of both sexes and is responsible for the manufacture of all parts that have to be made with the aid of such machines as lathes, milling machines, grinding machines and so on. Parts made in this way necessarily have a very high degree of accuracy, and these are in fact manufactured (in many cases) to within a few thousandths of an inch of the required nominal drawing dimensions. It is, indeed, the department where the solid material is turned into the finished parts.

The next work involved in the making of detail parts is that in which sheet metal is used. Nowadays many parts of the aeroplane are made from light alloy sheets. For example the skin or covering of the whole aeroplane, except for some portions of the tail unit, is often of this material and the use of this form of construction will need several specialized methods of manufacture and large numbers of highly skilled craftsmen. The methods formerly used to shape the flat sheet was to beat it into shape by hand—hence the term "panel beater" often applied to sheet metal workers. The latest method involves the use of mechanical presses to obtain the required shape.

Other small fittings made from sheet metal are stamped out in hand-operated stamping machines. These parts frequently have to be drilled for attachment to other parts by rivets or bolts, and this is done in small drilling machines. Such work is carried out in the fitting shop, mainly responsible for small parts made from the thicker gauge sheet metal. Even in the fitting shop, a large assortment of small jigs is used for the various processes involved, such as bending, shaping or drilling; but there is another factor that has to be considered.

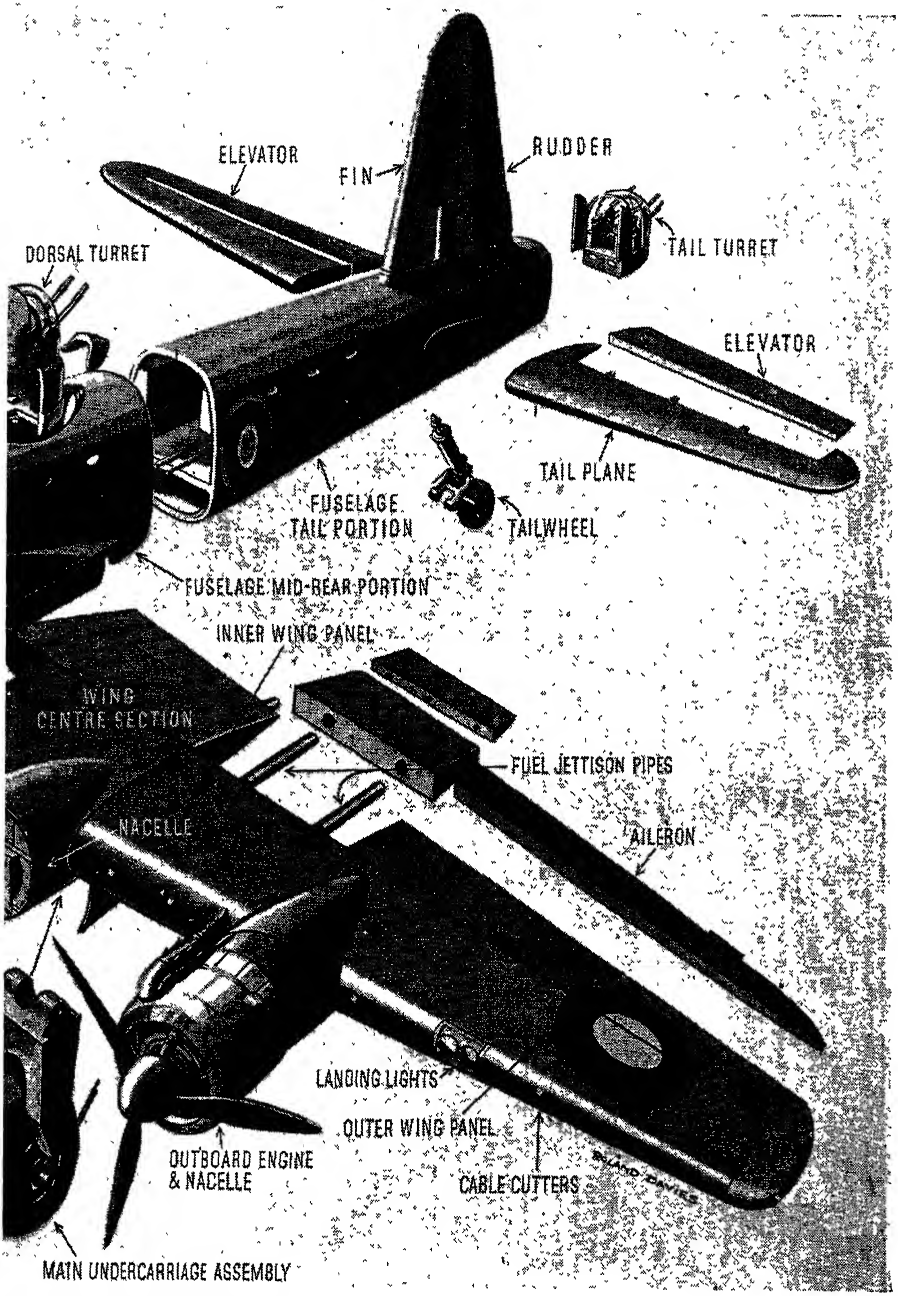


WORKING ON A WING
Mass production of aircraft needs rapid training methods for workers. Here are seen two trainees engaged in learning how to drill holes in a partially completed wing.



A FOUR-ENGINED BOMBER;

FIG. 4. *Above may be seen an impression of a typical modern, four-engined bomber. Although not based upon any one kind, it illustrates the main features of bomber design that are common*



MAIN CONSTRUCTIONAL POINTS

to all of these armoured monsters of the air. It must always be remembered that individual peculiarities will exist in specific types designed for certain kinds of specialized operational flights.

FINISHING FUSELAGES

These fuselages for one of the most famous of fighter aircraft have left the jigs and are being finished. The cockpits can be seen, and the space to be occupied by the fully supercharged Merlin II engine which is capable of producing 1,030 horse power at 3,000 revolutions per minute at 16,250 ft.

A very important addition to the actual manufacture of the detail parts themselves is their protection against the effects of moisture or corrosion. There are two main departments which deal with this. First is a stove-enamelling shop in which some of the parts are sprayed with enamel and then baked in ovens to give a hard and lasting protection. The second department deals with parts unprotected by enamel, but by some form of plating or deposition of a corrosion-resisting metal over their surface. This is done by a number of different processes,

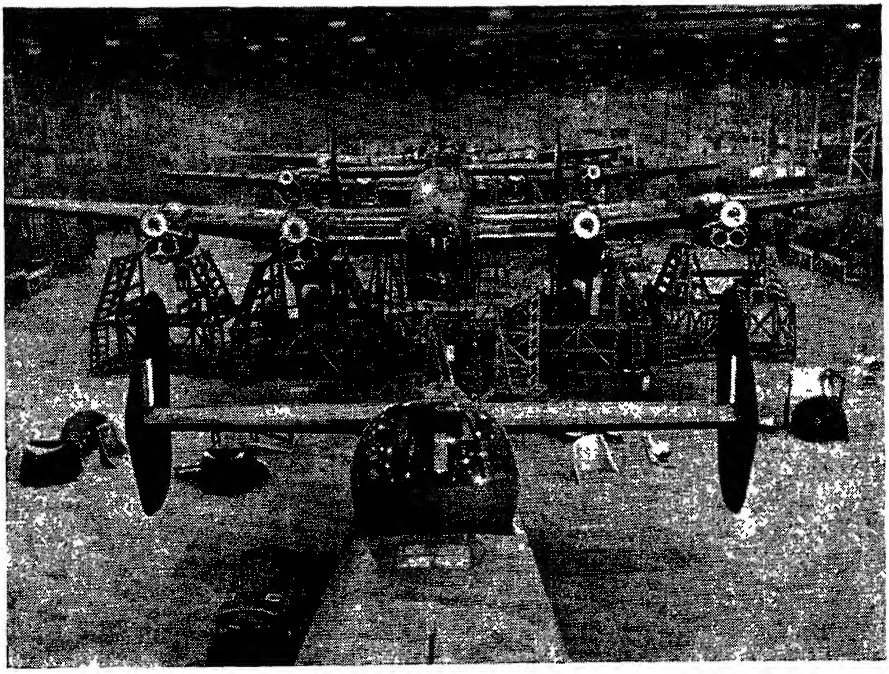
the most familiar being the "anodic treatment" given to duralumin parts resulting in a glossy light grey finish. This protection is produced by immersion in a tank containing a solution of chromic acid through which an electric current is passed. This results in the formation of a thin protective plating over the surface of the various parts concerned.

Steel tubing

Steel tubing plays an important part in aeroplane construction and is frequently built up into structures in which the various tubular members are joined by welding. Some fuselage frames are entirely built in this way. The tubes are cut to length in the fitting shop and any necessary machined fittings, such as attachment lugs, are produced by the machine shop. It is then the responsibility of the welder to join these parts together to form the required structure. Other parts, excluding tubular structure, are frequently joined by welding as in the case of some small sheet metal steel fittings of the type previously mentioned as the product of the fitting shop.

In hand welding, the strength of the joint depends entirely on the operators' skill, and all welders engaged in aeroplane construction are periodically required to submit test specimens of welded joints.

The preceding few examples have shown some of the various types of work that go into the manufacture of detail parts. The next stage, it will be remembered, is the assembly of these parts into the various larger sub-assemblies which are themselves eventually assembled to form the main components.



NEARER ITS TARGET

FIG. 5. *A "Halifax" bomber nears completion in the assembly line. It will be noted that wings, nose, engines, and tail have all been placed in position. Two complete rows of this kind represent the nine different stages from receiving the centre section to fitting the propellers, and finishing the job.*

Riveting is used a great deal for the attachment of members and for holding the sheet metal skin of the wings or fuselage in place, and many riveters will be found at work throughout the sub-assembly shops. Some hand riveting is also carried out in the manufacture of detail fittings in the fitting shop.

As all the sub-assemblies are completed they are subjected to the usual forms of inspection before being placed in stores in readiness for still further assembly into main components. In the assembly shops will be seen complete wings, fuselages, tail units and so on in various stages of completion. As in the other assembly shops, the sturdy metal jigs, which hold the parts to be assembled in their proper relation, will be apparent (Fig. 2).

Fabric covering and doping

So far no mention has been made of the use of fabric as a covering for the wings or fuselage. As already stated, thin sheet metal is commonly employed for this purpose nowadays, but in some aeroplanes fabric is used quite extensively. In most aeroplanes, however, it is used for the covering of such parts as the rudder and elevators of the tail unit. Thus before leaving the subject of main component assemblies it is advisable to visit the department in which this fabric covering is put on to the structure. Here, as would be expected, the work is carried out almost entirely by women, numbers of whom may be seen busily cutting the fabric to shape and skilfully sewing it on to the structure.

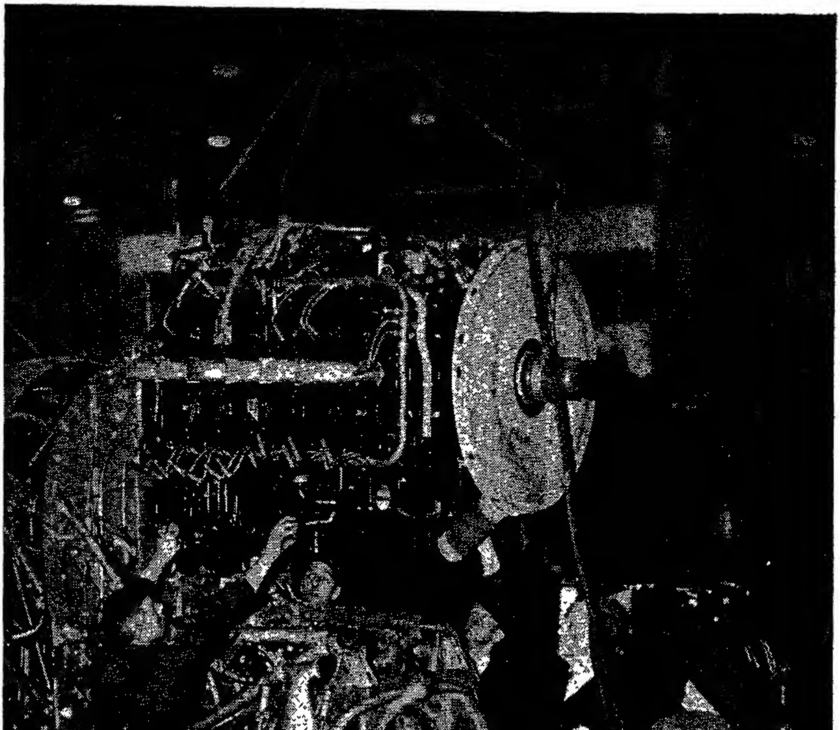
Of itself, the fabric covering is insufficient and must be made waterproof and "drum-tight" by the application of a special paint known as dope. This is done in the dope shop, where the covered components are sprayed with dope by means of spray guns. The atmosphere of this shop is noticeable for its strong smell of "peardrops" from the amyl acetate in the dope. Unless a mask is worn, this atmosphere would soon become very uncomfortable, though extractor fans are provided to change the air-frequency (Fig. 3).

It must not be thought that only fabric-covered components are treated with a dope finish. Light alloy skin-covered components will also be given such a finish, not because they need waterproofing or tightening, but to add the well-known camouflage finish. This work is also carried out in the dope shops.

The final stage is reached in the main final assembly shop. Here will be found rows of aeroplanes being assembled (Fig. 2). As each stage is completed the assembly is moved along, growing more and more complete, until it reaches the end of the line in the finished condition. At various stages the controls and instruments are connected up and tested, the undercarriage mechanism and bomb doors operated, engines installed, propellers fitted and so on. The aeroplane is weighed in the completed condition and the position of its centre of gravity found. All that remains is the final inspection.

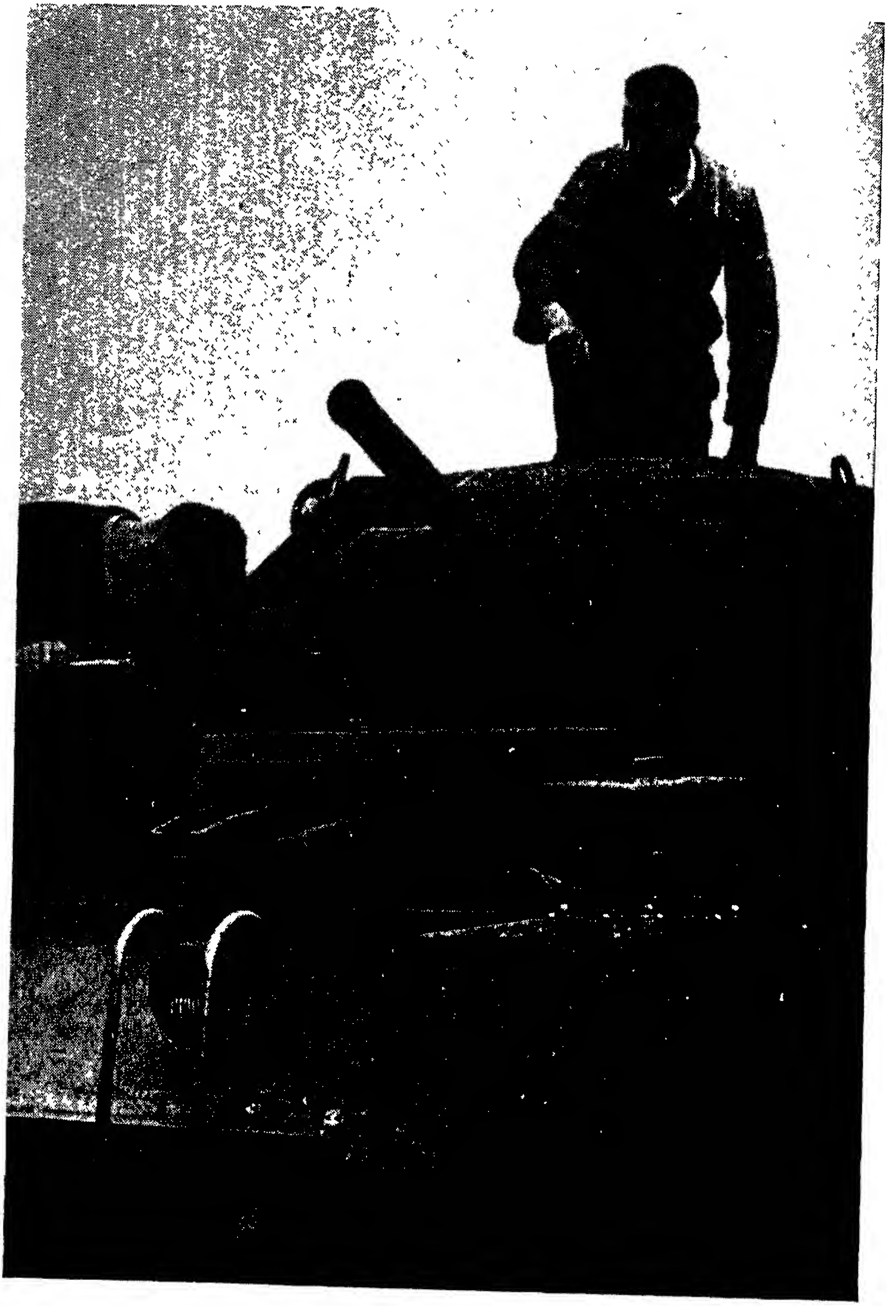
Triumph of teamwork

In so general a survey as the present, it has been impossible to mention all the people engaged during the various stages of construction. To name a few only of the jobs that have not been discussed, there are tool setters, progress chasers, stores keepers, riggers, metallurgists and many more. In addition no mention has been made of wood-working craftsmen, employed for specialized tasks in factories which build aeroplanes of wooden construction. In spite of these omissions it is hoped that the discussion has helped our Mr. Smith to a clearer idea of the work. At the least, he will agree that the job, whatever it be and however seemingly "unimportant," is a definite operation in a large and comprehensive organization.



INSTALLING ENGINE IN "TYPHOON" FIGHTER

In the busy but carefully ordered main assembly shop, an aircraft is given its motive power. An engine power unit is being hoisted to the aircraft pick-up points. The lifting tackle is hung from the roof of the main assembly shop, while a spacer frame is used to keep the cables of the sling well away from the descending engine, which is being lowered into place for connecting up.



READY FOR ACTION

After leaving the end of the assembly line the finished tank undergoes a rigorous testing under conditions which ensure that any weaknesses may be discovered and rectified without delay.

HOW TANKS ARE MADE IN BRITISH FACTORIES

By Guy Leonard

Planning the armoured monsters of modern war. Factors that the designer must consider. Protection and fire-power versus speed. Problems of sub-assembly construction. Main assembly plant and its workers. Making and fitting tracks. Vital accessories. How the turret is fitted. Rôle of the test drivers.

Tanks, like ships, have character. It is built in with the engines and the guns. It derives from the men and women who build them. To those men and women this chapter is dedicated, for they deserve every tribute that can be paid to them.

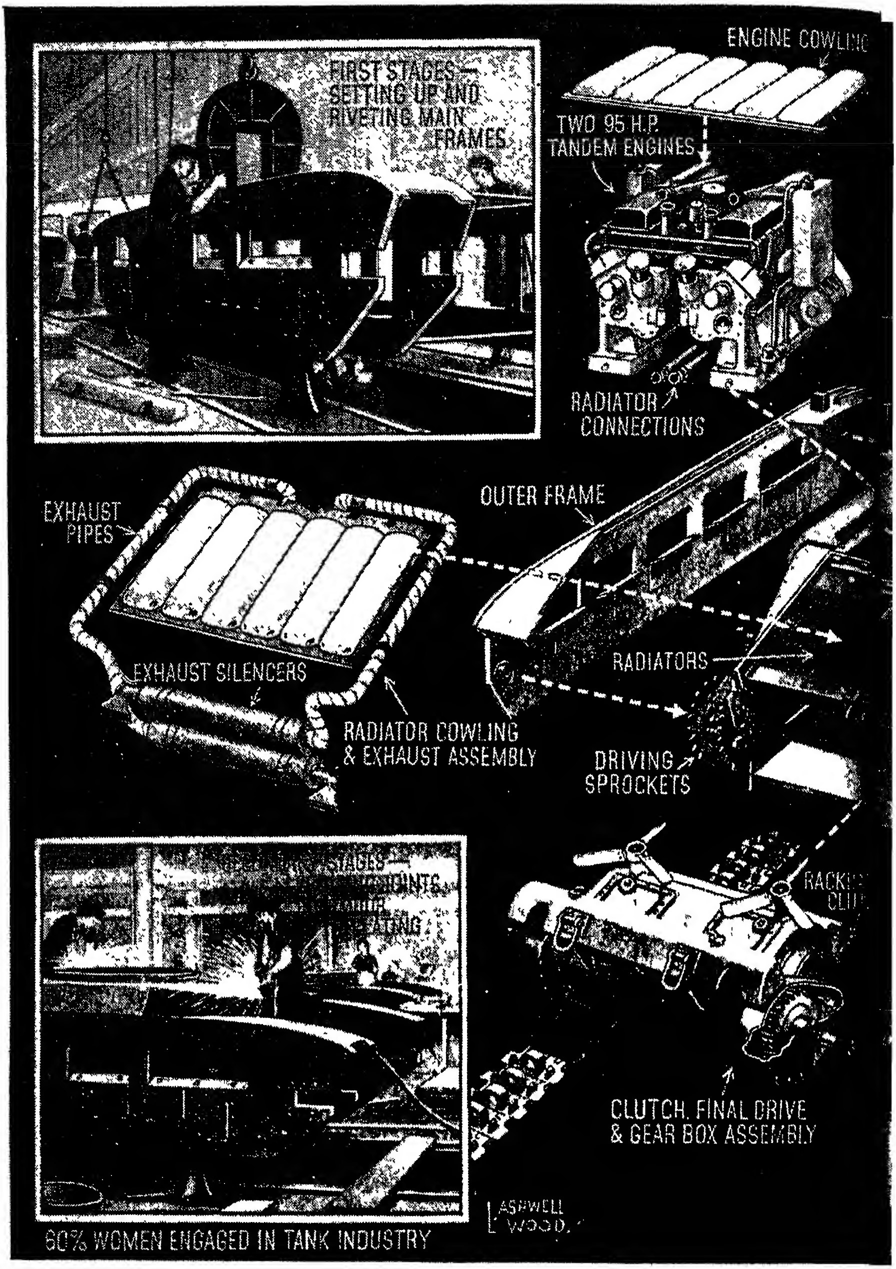
Those men and women know little of the birth-pangs of the tank. When they begin work, its final form has been decided. It starts life as an idea, takes tentative form on paper and emerges as a prototype. Only when this has been satisfactorily proved, does production begin.

The Army would like the ideal tank with heavy guns, armour that will resist any shellfire, capable of enormous speed, and with an unlimited range. Although we can aim at it, as we all know, we cannot have perfection, and so the Army and the designers and engineers collaborate to achieve the best they can in the various types wanted for different purposes.

It is not generally appreciated how much labour and how much time go into the construction of a successful tank type. On the face of things it would seem that all that has to be done is to decide on the type, draw the plans, and then ask the factories to make it. It has been known to take about five years from the moment that it is decided to build a new tank until it is ready for mass production. This is a grim reflection on the preparations which the Germans must have been making in the years following Hitler's seizure of power!

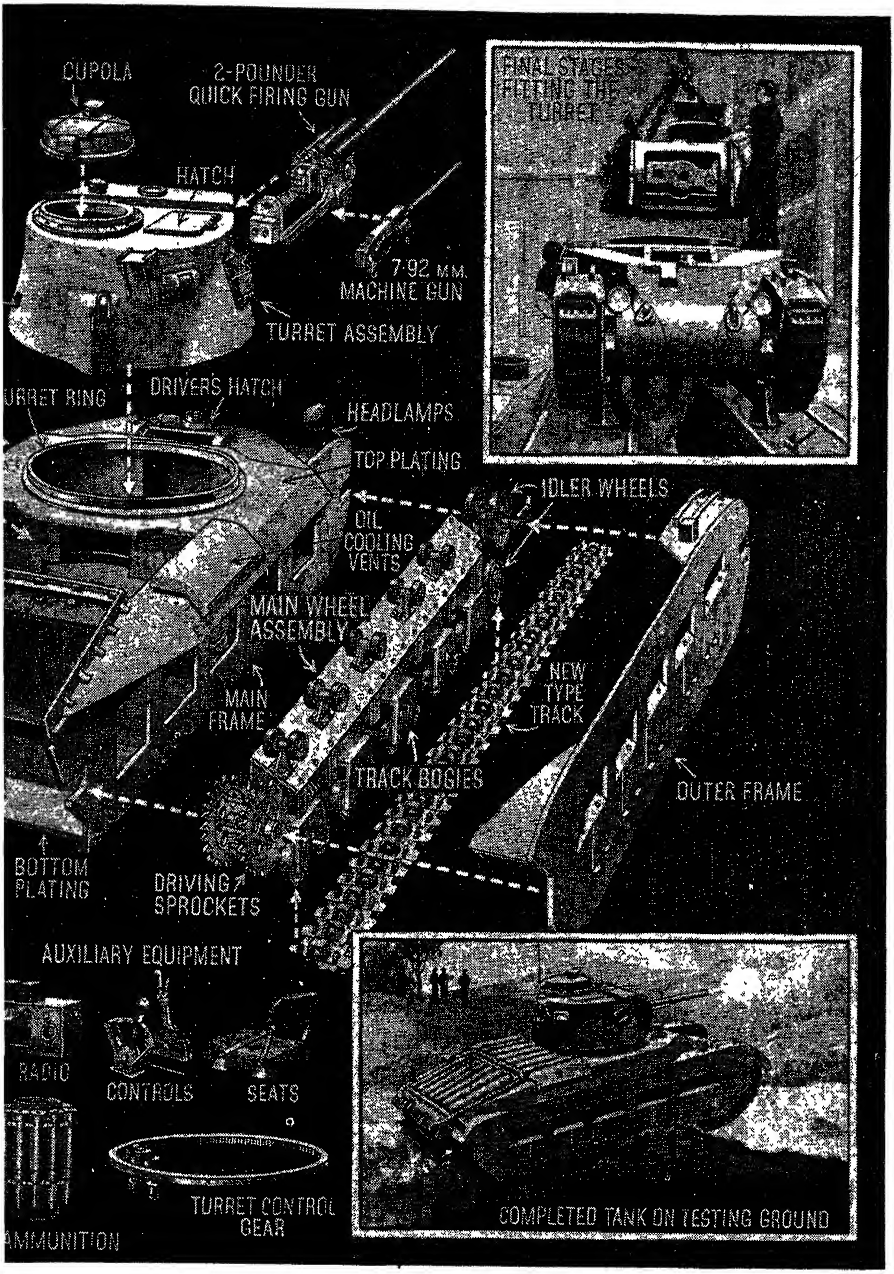
First of all one has to decide on the sort of battle one expects one's tanks to fight: will they be needed for battling against other tanks, for reconnaissance, or for supporting infantry? The Germans had four types: the light reconnaissance tank (there were two of these, Marks One and Two), the Mark Three for tank battles, and the Mark Four for infantry support. The two last types were more or less interchangeable. This problem settled, one has then to decide how much armour, how big a gun, and what speeds are required. All these factors are interdependent. To the tank designer, armour and guns represent weight requiring engine power to move it. If the tank is big it will require a very large engine, and even then will not be very fast. If the designer aims for speed he will try to make his tank small. A small tank means a small gun, otherwise there would not be room for the recoil—or for the ammunition.

Having settled roughly the principles on which he is going to work, the designer passes his ideas on to the design department which get down to problems of weight, armament and speed. It will take them months—working as hard as they can—to find the answers to the



HOW MODERN TANKS

FIG. 1. *In successive stages the construction of a tank is illustrated above. In one tank there are as many as eight thousand different parts, and to simplify constructional methods different units are sub-contracted and eventually sent to the final assembly plant where they are co-ordinated.*



ARE MASS PRODUCED

Tank assembly differs from normal mass production methods because no conveyor belt could carry the weight of the growing tank. Therefore the production line consists of two rows of tank hulls, specialized workers moving from one hull to another until the tank has been finally completed.

problems the designer has set. When their work is done they will have produced a series of drawings capable of translation into a tank that is more or less a full-size working model. This is the stage at which the "real work" begins, but this stage will not normally be reached until a year after the drawings have been completed, because every part—and there are thousands of them—will have to be specially made.

Adjustments and redesigning

Presuming that the designer's ideas are fundamentally sound and that the tank goes when the engine is started, a long process of trial and correction now begins. It should be borne in mind that all the parts of a tank are related closely to all the other parts, and that any adjustment in one may mean adjustment in many others. Adjustments may mean the manufacture of new parts, and time slips by. It is not always easy to discover the cause of a fault, and it may mean weeks of patient running back and forth under particular conditions before it is traced. Changes may have to be made merely to discover what is wrong—and there are so many things that can go wrong in the early stages of the life of a tank.

Perhaps the transmission gives trouble. This may be due to the track, the gearbox, the engine, the suspension, or even to the shape of the hull. Perhaps the suspension is not strong enough to stand up to the innumerable bumps it receives. This will mean redesigning the springs and shock-absorbers, the hull to take these and possibly the weight of the whole structure. At the end of a year it may be found that the design as first laid down is impracticable and a fresh start must be made. Rarely is it as bad as that, however, but a tremendous amount of redesigning is inevitable.

When the first one or two models have been tested—perhaps to destruction—other prototype models are built and likewise tested. It does not matter how many times the tank breaks down when being tested, but it would be fatal if it fails in battle. Therefore, every possible weakness is sought out on the testing-ground, and every possible care is taken to set right the discovered faults.

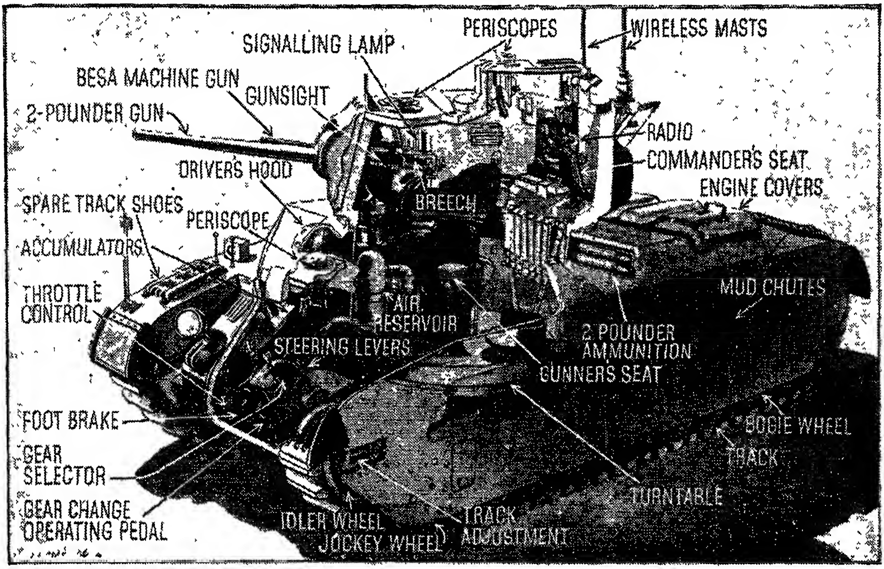
In building railway engines or motor cars there is a vast field of experience on which the designer can draw. In addition a new car or engine is not often revolutionary in design—although its makers may claim so. These things are built on the basis of known facts, but there are relatively few such known facts about tanks because they are only put to the ultimate test in actual warfare, and were born only in the First World War.

Planning ahead

In addition, cars are designed to run on smooth, well-surfaced roads, railway engines are made for the smoothest track of all—the railway line, where a gradient of one in a hundred is thought to be steep. In action the last place one may expect to find a tank is on the road because there it is a target for the enemy. It will have to go across country, any sort of country, it may even have to operate in mountains. It will need to wade streams and surmount obstacles.

After four or five years the design may have become more or less settled. The prototypes will show that the type is "battleworthy," and mass production may begin. Then someone will have an idea for improving it. That idea, if it warrants the delay in production, will be tested on some of the finished models. If it be satisfactory it will be put on all the new ones being made, and later on those which were made beforehand.

No wonder, then, that tank designers are usually worried-looking men whose vocabulary contains more "ifs" and "buts" than almost any other person's. That we



MAIN COMPONENTS OF A TANK

How the most important of the eight thousand components which go to make a modern tank are arranged is shown in the above illustration. Positioning of guns, periscope, control lever and radio is carefully planned to give maximum efficiency with minimum discomfort to the crew.

have succeeded in building such good tanks as we have is a tribute to our designers and to the British capacity for improvisation.

While the prototypes are being built the firms who will undertake the actual production are selected, and formed into a group. Every detail about these firms has been card indexed and their capacity is exactly known. Usually the firm which has made the prototypes acts as "parent" to the group, so that all the experience and specialized knowledge which it has acquired so painfully during the months of experiment is passed on to other firms.

In a tank there are as many as eight thousand different parts and a total of up to 40,000 pieces altogether. Therefore, arrangements are also made in advance for the production of all the small parts, the rivets, the armour plate, the gear boxes, the transmission, the suspension (or springing) and the engine. This work will be done sometimes by specialists, but often by people who have never before had the remotest connection with vehicles of any kind, least of all fighting vehicles.

Some of the smaller firms will do a certain amount of sub-assembly: wheels and springs will be put together to form the suspension: the complete gear-box is made up from the gear wheels, shafts and case; and the engine, the pistons and rings which may be produced by specialists in these things, will be built up, tested and passed on as a complete unit. At gun factories other workers will be making the guns and mountings. If the new tank is to have a cast turret, foundries will be preparing the moulds and metal.

All these bits and pieces are brought together at the main assembly plant. The thousands of parts are put together in their predestined pattern. Here one can see the purpose behind the pieces and the fulfilment of the designer's dream.

All this sounds very simple. It is, in fact, the barest essentials of the elements of production. In order to put the thing into its proper perspective it may be useful to consider for a moment just what happens to an individual component. Not something obviously difficult like guns or engines, but something relatively easy such as armour plate, or wheels and suspensions, or even tracks.

Making the armour plate

So let us start with the armour plate. Its weight, thickness and shape are determined by the type of the tank, the weight the tank can carry and its shape, for it will have to fit together round the hull even closer than a jig-saw puzzle. The plate is made in a steel works from iron-ore and scrap, pressed and rolled into the desired thickness and shape. It is an encouraging thought for the ardent collector of salvage that some of the metal he or she handed over may have been in tanks which routed Hitler's divisions. The railings which used to line your front garden may have gone into the guns and ammunition which enabled those tanks to fight through to victory.

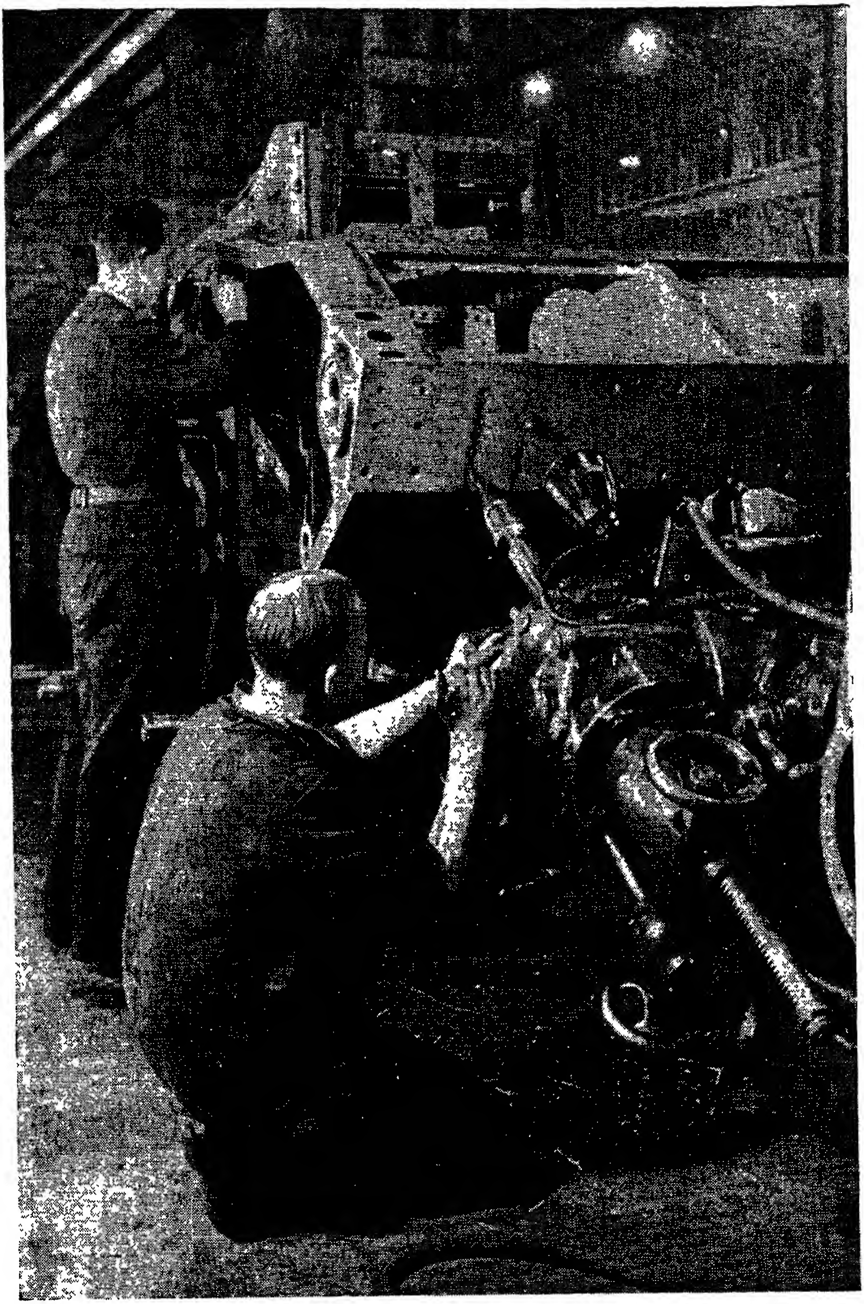
Armour plate, however, does not consist entirely of ore and scrap, but also of various hardening and toughening materials such as wolfram, nickel and chromium. It is these that give the steel its strength and enable it to resist the impact of shot and shell. There is continuous research to discover new and better ways of toughening steel, of getting more resistance for the same weight.

It is easy to imagine how difficult it is to cut pieces off this very tough plate once it has been shaped, and so, as far as possible, it is made exactly to size. When it is fitted to the tank the gaps between the plates must not be greater than one two-thousandth of an inch or a weakness would result which might be fatally discovered in the heat of battle. The skill of the British workman, famous throughout the world for generations, ensures that these very fine limits shall not be exceeded.

Now let us look for a moment at the tracks on which the tank moves. We must not forget that a tank actually lays down for itself a steel path on which its wheels run. This track is made up of a number of track plates, forming an endless belt, linked together by very strong steel pins. When the tank is moving the part of the track which is in contact with the ground is, of course, quite still—that is, relatively to the ground and not to the tank. But part of the track is moving, moving fast, in fact twice as fast as the tank itself. Thus it must be very flexible. The track is driven by two sprocket wheels at the rear of the tank. That is their single function. (See Fig. 1.)

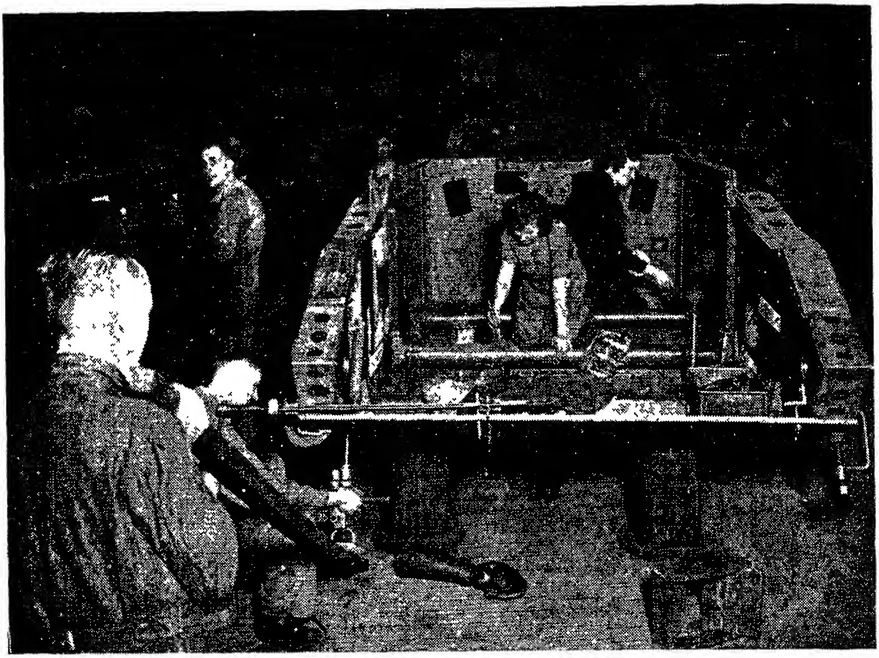
When a tank is running over uneven ground the first shock of contact with the bumps is taken by the tracks. When obstacles are being surmounted—walls, ditches and tank traps—the immediate strain is thrown on to the tracks. When a tank is climbing hills or descending into valleys, the tracks have to bear the weight and strain of climbing and descending. Small wonder, then, that the tracks have to be enormously strong. However strong they may be, they are still the most vulnerable part of the tank, for if one plate or pin be broken—and there are many of them—the tank is completely immobilized, and a stationary tank is a sitting target for enemy guns and bombs.

Women play a big part in making the tracks. It is a hard, dirty, smelly, unpleasant job. First a mould is prepared by packing a pattern into sand in an iron box. This pattern has exactly the shape of the track plate. The pattern is removed and into the space left molten steel is poured. When the steel has cooled and hardened, the fastenings of the box are knocked away, the track plate taken out and any odd pieces of metal that may be on it



DRILLING THE HULL

FIG. 2. *In order that various components may be attached, both inside and outside the tank, holes have to be drilled through armour plate. Above is shown the process of drilling the hull of a tank.*



IN THE MAIN ASSEMBLY SHOP

Multiplicity of the operations which go to make the completed tank may be glimpsed from the above photograph taken in the main assembly shop. Drilling operations (see bottom left), painting and fitting proceed simultaneously as the rows of tanks gradually take their familiar shape.

removed. This is a hard, monotonous and dirty job, for it is necessary that each mould should be exactly like its forerunner.

The track plates are fitted together in the foundry where they are made, but are separated again for ease of transportation, to be re-united in the assembly plant.

Forty tons ride smoothly

It might be thought that it would be easy to make wheels and suspension units to run on the track which the tank lays down, but that is because we instinctively visualize cars when we think of wheels and springs. A car, weighing perhaps two tons, travels along a smooth road prepared for its passage, but a tank, weighing in some cases up to nearly forty tons, has to travel at speeds of up to thirty miles an hour across any sort of country.

Inside the tank is a lot of very delicate apparatus, varying from a powerful internal combustion engine to a beautifully designed radio set—not to mention a crew who, tough as they may be, can only stand a certain amount of banging about in their steel box. Therefore the suspension, or springing, must be stiff enough to absorb the greater part of the inevitable shocks, and resilient enough to allow the tank to ride easily. In some cruiser tanks the motion is rather like that of a yacht over the sea; the bumps are there but the tank rides easily and smoothly over them.

Cruiser tanks usually have what is called "knee-action" suspensions. That is to say, they bend much as the human knee does—almost exactly as the knee does in ski-ing. The unit is made up of a spring and a piston working in a

cylinder of oil, which takes on the duty of the thigh, and another length of steel joined on to it, which acts just as the lower leg does. The American "General Lee," "General Grant" and "General Sherman" have a different form of suspension.

Another of the, to the layman, surprising things about tanks is that many run on rubber tyres. Each wheel which runs on the track has a solid rubber tyre, and for this purpose a tank may need quite a lot of rubber. A "Crusader" tank has altogether ten wheels, five on each side, each about three feet high. Altogether the tyres on those wheels weigh about two hundred pounds.

The wheels and suspensions are usually assembled in one factory, and sent on as complete units to the final assembly plant. This practice of sub-assembly has proved of enormous value in speeding up the output of tanks, and it is obviously necessary for making parts like radio sets. It would be unreasonable to expect the factories which do heavy engineering work to undertake this delicate and complex task. Moreover, spreading the work in this way enables thousands more people to be employed, thus speeding up production.

How "bottlenecks" are prevented

To feed all the sub-contractors and sub-assembly plants with material and parts demands a vast and complex transportation system. Supplies must be adequate and punctual. If there is delay in delivering one item of raw material, that delay will be felt through every plant working on the type of tank involved. Suppose, for example, there is a hold-up in sending iron ore to the blast furnace where the pig-iron is made. The blast furnace will be unable to send any iron to the foundry where the steel track plates are made. It may not be possible to arrange for an alternative source of supply, so the track plate foundry will also fall behind with deliveries, The final assembly plant will then have tanks complete except for the tracks and will not be able to get them off the assembly line. The factory will soon become choked with parts which cannot be assembled for lack of room, and further deliveries will have to be refused. This backward movement will be reflected in the other component factories which, in turn, will become clogged with parts which they cannot deliver. Eventually they, too, must stop, and so production may cease altogether for a time because one tiny cog in the machine has slipped.

It is the duty of the planners and progress officers to see that, so far as is humanly possible, stops of this kind do not happen. Alternative sources of supply must be found. Extra manufacturing capacity must be sought out, and if necessary, other, less important work must be put aside for a time until the bottleneck is smashed and production flows freely.

In the production line

Now let us see what happens in the final assembly shop, where the tank takes shape and the planners' dreams fructify; where the various components and sub-assemblies go in at one end and the finished tank emerges at the other ready for testing.

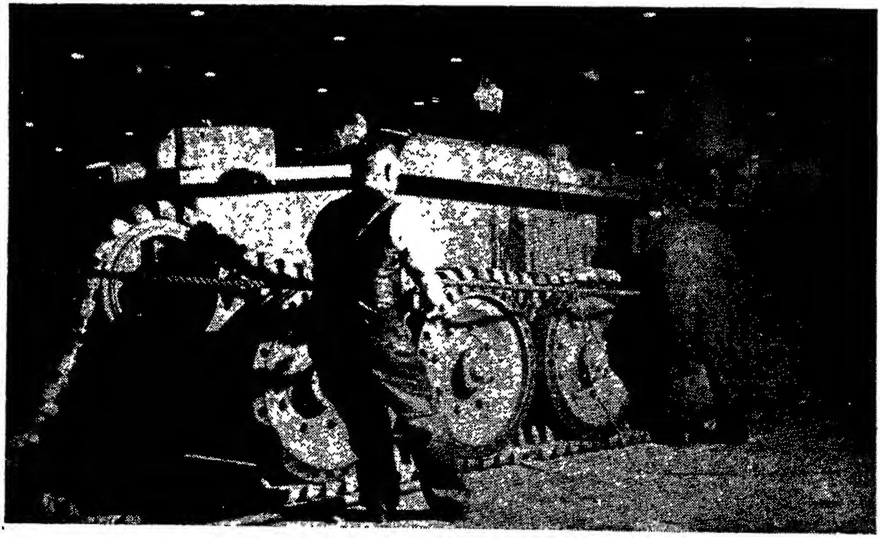
Usually we shall find that these plants are heavy engineering works, well accustomed to the handling of weighty machinery. There will be overhead cranes in each bay, and the factory will be laid out much on the lines of a mass production factory, although mass production methods are not followed exactly because no system of conveyor belt could possibly carry the growing tank from its inception to its completion. The tanks are pushed along the production line as each stage is completed. The production "line" will consist of, probably, two lines of tank hulls in various stages of progress. Specialized workers move from hull to hull to add their little piece, or do their particular job, until the tank is complete.

It is finally filled up with petrol, oil and water, and sets off under its own power on its way to the testing ground. As it goes on its way the line of tanks moves up, and at the other end of the line workers begin to bolt together plates in the shape of a box. Later on they will be riveted together, and the hull will begin to take shape. Meantime, there is much to be done. The turret for this particular tank is made up of a number of plates which have to be welded together. In the welding shop we shall find this work in full swing. The turret ring, on which the turret swings round, has to be machined and teeth cut into it. Similar teeth on a small wheel attached to the bottom of the turret will engage these.

Holes have to be drilled into the armour plate in order that various gadgets may be attached both inside and outside the tank (Fig. 2). In these screw threads may have to be cut so that the gadgets may be screwed on. This is called "tapping," and it is one of the operations in which the woman's "touch" has proved to be most valuable. Most men try to force the hard, brittle "taps" through the tough metal, and there are breakages in consequence. It is impossible to avoid these altogether, but the gentler hands of women, coupled with a patience which is almost equally characteristic, save thousands of taps every week. Nor does this only save taps; it economizes time and materials for men who have to make those taps with precious hard steel.

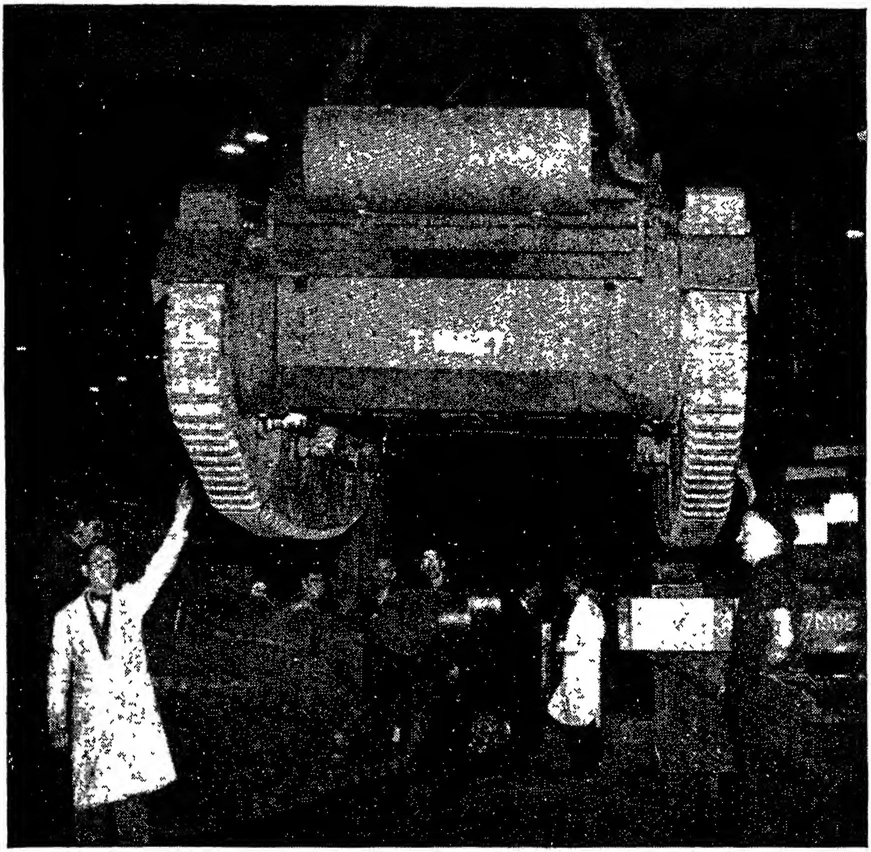
Bullet-proof rivets

On the other hand, women are not usually as good as men at riveting. It seems that the female nervous system cannot stand up so well to the continuous vibration which the pneumatic riveting machine sets up in the operator. The rivets are bullet-proof, but they have to be so made that they cannot be forced out of their holes and fly round in the tank.



PUTTING ON THE TRACKS

FIG. 3. *An endless belt of plates, held together by steel pins, forms the steel path upon which the tank moves. Their importance can be visualized when it is said that one faulty track, pin, or fitting may immobilize the tank at a crucial moment in battle. Above is seen workmen engaged in the task of pulling these track plates over the wheels, they will then be joined together.*



UP SHE GOES !

Overhead cranes in each bay are a feature of the tank assembly factory. The photograph shows an eighteen-ton cruiser tank of the "Crusader" class being hoisted as it nears the final stage in its progress through the factory. It will be noted that at this stage the tracks have already been fitted.

Another woman's job is electric wiring. In a tank this is very complex and, understandably, the wiring is put well out of the way of the crew and moving parts. This work demands, therefore, patience and the ability to stay in awkward positions for considerable periods. Women do this work extremely well.

Once the box, or hull, is complete, axles, wheels and suspensions are put into place; the engine is dropped into its bed, gear box and transmission are added thereto. Fuel and oil pipes are fitted; instruments put in the driver's compartment and seats provided for the crew. Meantime, in an instrument makers' shop somewhere else, the "eyes" of the tank, the periscopes, which enable the crew to see when the tank is completely closed up for action, are being built of steel and glass. By a very ingenious contrivance the glass lens of the periscope may be changed in a matter of seconds should one get smashed during a fight. It can be done, too, without the necessity of anyone moving from his place in the tank.

Finally, the turret is carefully lowered on to its ring (Fig. 4). Then the track plates are assembled into a long strip, pulled over the wheels, tightened, and joined together (Fig. 3). The petrol, oil and water tanks are filled and the tank is ready to undergo its first trials.

Before the trial runs begin, everything is given a check over. This is in addition to routine checks which have been made at every stage of manufacture, but the test driver must satisfy himself that the tank is absolutely ready for the tests it is about to undergo. On this first trip it may be a dragon without teeth. It is quite likely that its guns have not yet been fitted. It may stay like this until its maker's trials are finished.

What the test driver looks for

The test driver does not at once tear round the testing ground to discover the new tank's weaknesses. This is the last thing he does to it. At first, he goes very gently, in bottom gear, to see how it responds to the controls. He accelerates the engine, watching all the time the many gauges. He watches fuel and oil consumption, temperature and smoothness of running at various engine speeds up to the maximum—and over it. Still in bottom gear, he turns to right and to left, feeling all the time how well the tank responds. Then he changes gear and goes through a similar performance in second gear; then in third; then in top. Then he tries changing gear up and down, and only when he is satisfied with all these things does he begin testing over bumpy ground.

When he is completely satisfied that everything is as it should be, the tank is taken back to the shop to be examined in every detail. With this examination complete, it is taken out again and once again tested in detail. But now, when the details have been checked, it is taken on to the testing course. This course is deliberately selected to offer every kind of difficulty that may be met with in operations. If they do not exist naturally they are substituted artificially. Finally, the test driver takes the tank over the test course at maximum speed. And all the time the driver is watching, watching. At the slightest sign of weakness in any respect he will stop. The weakness will be put right and tested again and, if necessary, again until the tank has proved itself up to the very high standard our fighting forces have the right to demand. Then, when the tests are finally completed, the tank is taken back to the shops and once more overhauled in the minutest detail. If the examination proves that everything about it is in order, it is taken to an ordnance depot where the guns are, if not already there, fitted.

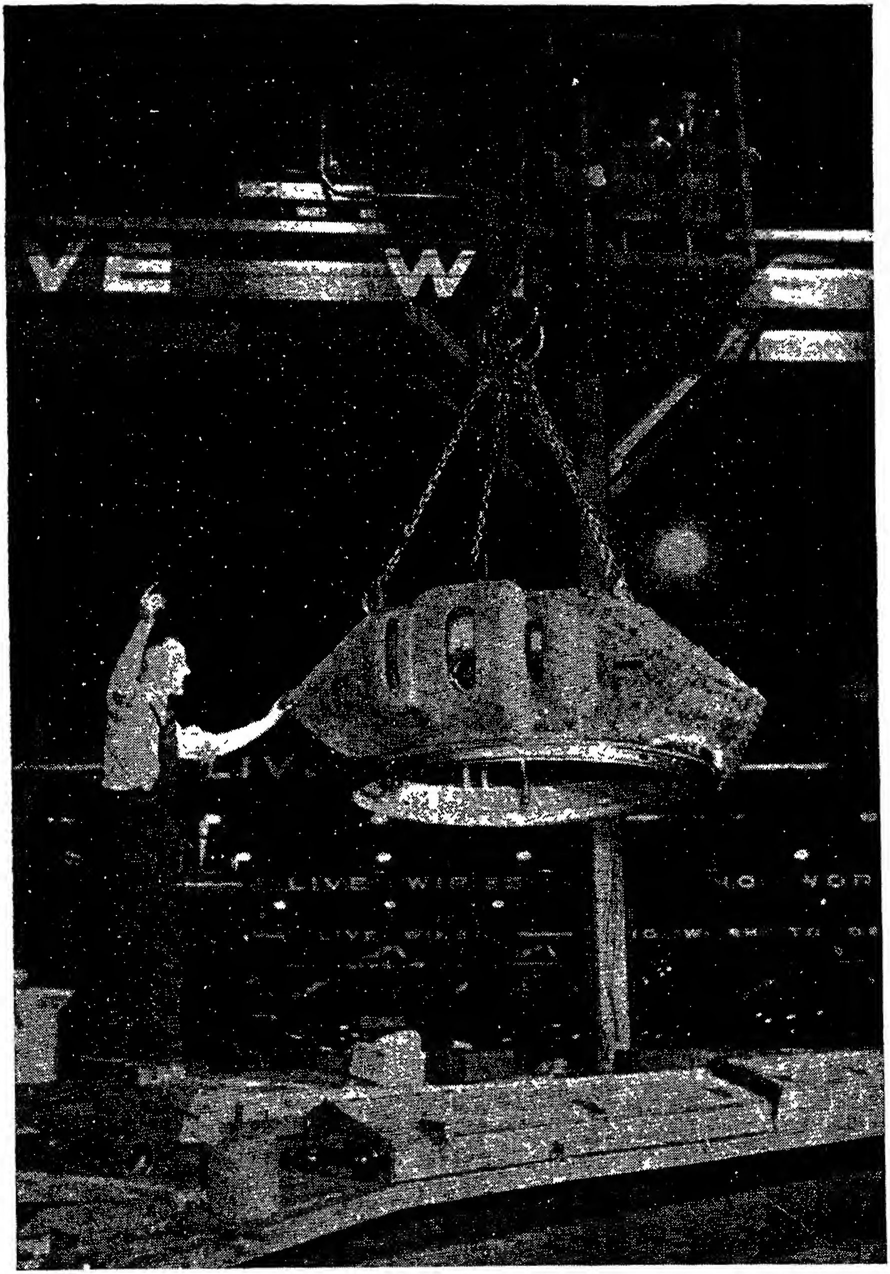
Now a word about the guns: the two-pounder and six-pounder anti-tank guns, and the 7.92 mm. Besa machine gun. Combinations of these weapons comprise the armament of most of our tanks. At one time, in fact, the two-pounder was the main armament. It was designed before the outbreak of the Second World War for fighting in the close country of Europe. Its most effective range is comparatively short, about four to six hundred yards.

A deadly weapon

Tank battles in Western Europe were expected to be fought at such ranges. It has a high muzzle velocity and, in good hands, can be a deadly weapon. The advantages of its small size are that it occupies little room in the tank turret, thus enabling a relatively large supply of ammunition to be carried, and its rapid rate of fire.

Developed during the war, the six-pounder became the most effective gun of its size in the world. It has replaced the two-pounder as the main tank gun.

A gun is as precise in its workmanship as an expensive watch, and as tough as a



LOWERING THE TURRET

Fig. 4. *Here we see a late and important stage in the assembly of a tank. Guided by a worker, who is signalling his requirements to an operator of the overhead crane, the turret is being lowered with care and precision into its appointed position on the hull.*

battering-ram. It must be able to stand up to the shock of an explosion that will hurl a projectile from its muzzle at enormous speed, and be so built that it will direct that projectile accurately to its destination. These qualities call for the most careful workmanship and the finest materials. "Near enough" is not good enough. "Exactly right" is the demand, and the men and women of the gun factories meet that demand with a speed and a skill that have confounded our enemies.

Forged from finest English steel, the gun begins its life as a solid piece of metal like a gun in shape, but a little bigger in every way than it will be when it is finished. It goes from the forge to the gun factory where hundreds of operations are carried out on it. The gun is first bored through its length and then roughly machined on the outside. Then it has to be bored and smoothed inside till it resembles a circular mirror; and rifled to make the shell twist as it is fired. This makes the shell travel nose first. A chamber is cut out at the breech end to accommodate the shell and cartridge. A breech-block must be made to close the breech effectively when the gun is fired. A breech ring joins the breech-block and the barrel together. On the breech-block a firing mechanism is fitted.

Gun-making

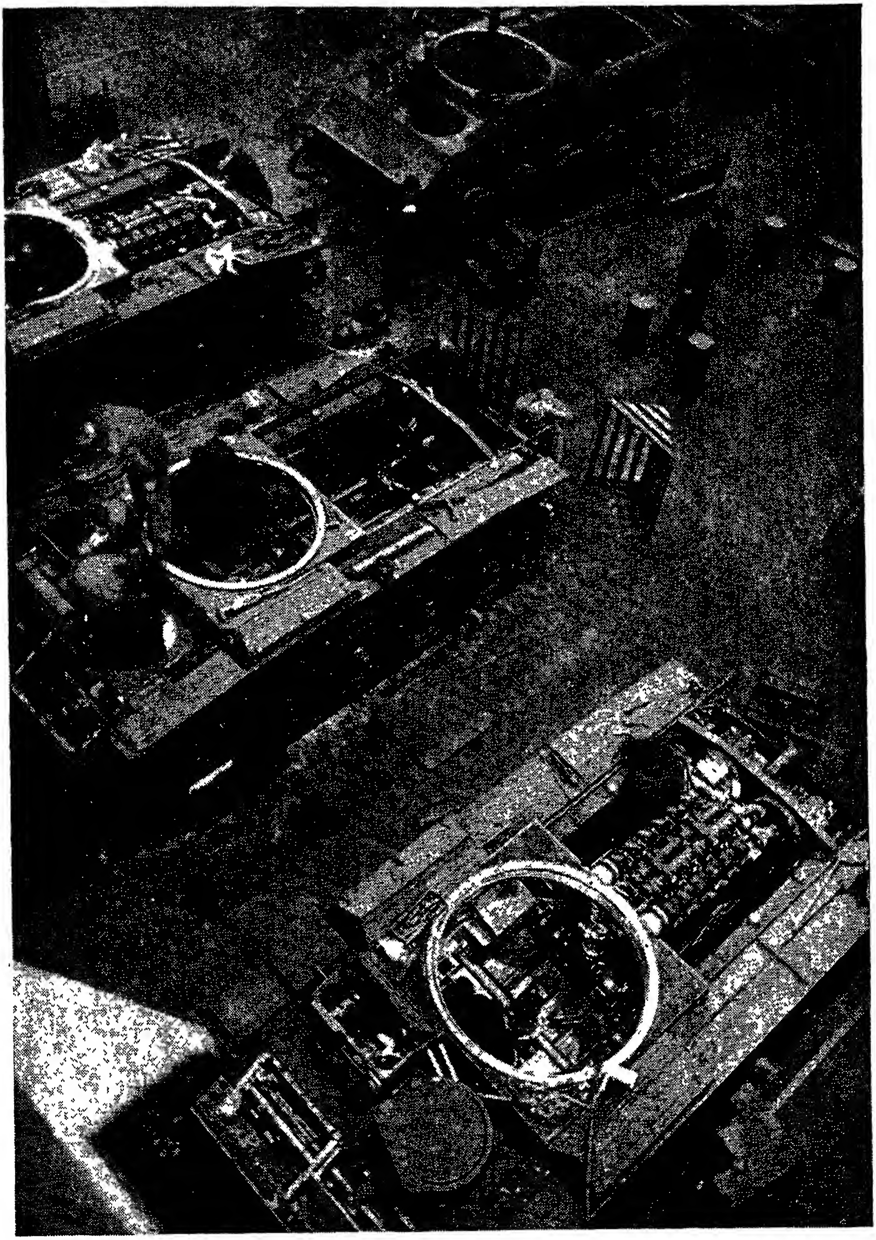
Of all the delicate, highly-skilled work that goes into the gun, 80 per cent. has been done by women, who had not been thought capable of doing it. But under the urgent stress of war these women found in themselves qualities which even they did not believe were there. They did hard, heavy, monotonous work as though to the manner born, and excelled at it. The British Army has lavished praise on the makers of its guns, and by far the greater number of those workers were women. "Ordinary" women and timid little girls, whose only aim in life was to run a home and rear a family, found in themselves the strength and courage to become engineers controlling huge machines capable of cutting the hardest steel as they themselves would cut bread in a saner world. That magnificent strength and courage are a great national asset.

Special ammunition is made

In other factories women joined with men to make the ammunition that would feed those guns. That ammunition must fit the guns as perfectly as everything else about a tank must fit. Our tank crews praise the Lord *and* praise the ammunition!

One-third of the workers making tanks were women; two-thirds of the workers making shells were women; four-fifths of the workers making guns were women; and nineteen-twentieths of the workers filling the ammunition with explosives were also women. In the filling factories there is quiet, and it is fitting that it should be so where the explosives that propel the shells are handled. For those explosives make a noise but once in their lifetime and they must do it in a proper place. Everything that has been said about care and accuracy in workmanship is even truer of the operations that are carried out in the filling factories, and although everything that can be done to reduce risk is done, there is still the possibility of serious accident. That risk has been taken by these splendid women who, in their cool courage, were no whit behind the men in the front line.

In the making of every component that goes into a tank women have had their share, it may be greater, it may be smaller, but without them our tanks would number hundreds instead of the thousands which we now have. The victories of the men in the field were made possible only by the magnificent work done by women as well as men in factories on the home front.



PRODUCTION LINE

Above may be seen the production line, with the as yet uncompleted tanks in various stages of construction. The tank on the bottom right has been equipped with its engine and will soon be ready for the turret to be lowered on to its ring. The petrol, oil and water tanks will then be filled and the completed tank move off under its own power for a rigorous testing before despatch.

The batch delivered from the business end of the mixer, properly mixed, is trucked up, labelled and wheeled into the glasshouse to await the batch-filler, who feeds the various pots or tanks at correct periods so as to be ready for the glass-workers after fining.

Cullet is scrap glass. No wastage of metal takes place in a glassworks. Actually, broken scrap from other melts of the same make-up helps the fusing, thus giving homogeneity to the mixture by being incorporated and mixed in the batch. A characteristic general melt could consist of the following ingredients, in carefully prepared quantities: sand, felspar, dolomite, barium carbonate, soda ash, nitrate of soda, saltpetre, borax, manganese or cobalt (decolorisors), cullet.

As all the ingredients have to be melted at very high temperatures, in the region of 1,500° centigrade, a furnace is the primary necessity. Glass was and is universally melted in pots, these being set like eggs in a nest (Fig. 3), the nest being the furnace proper, and the heat being directly or producer-fired from a central or nearby fire of coal. Coal is still a leader in the fuel field with gas as a heating agent in many modern factories.

Pot-furnace heating

Imagine an underground cavern complete with fire bars and air channels. This is the chamber designed to promote the draught necessary for combustion, also acting as a chamber for cleaning out ashes, etc. At a higher level, on the next floor as it were, we have the "cupola." Here the stoking-up in the combustion chamber is carried out. Above this is the furnace proper (Fig. 5)

The heat is directed through the floor of the furnace or "eye," consisting of a round hole centrally placed in the "siege" or floor, which is usually of circular formation. Around this eye are situated the glass-melting "pots" or containers, placed very close together in radial formation. Enclosing the entire group of siege and pots are the furnace shell and flues. The furnace "crown" is a dome-shaped roof enclosing the pots from the chimney proper, above.

The whole action to promote the necessary temperature for glass-melting is the circulation of the burning gases from the eye around the pots. How this is done is clearly shown in Fig. 5, which gives meaning to the large conical chimney, so familiar and characteristic a feature of certain glassworks.

At a convenient level for the pot mouths, are situated openings in the furnace wall. These give access to the pots for filling with batch and withdrawing the molten metal when fined.

Tank furnaces

Another contrasting type of furnace is the tank. The combustion chamber, instead of carrying pots of molten glass, is so constructed that the lower walls form a large bath made of special clays and capable of holding an enormous quantity of molten glass. Owing to the quantities of glass it is able to hold and deliver without a refill, this type lends itself to the manufacture of the cheaper forms of glassware.

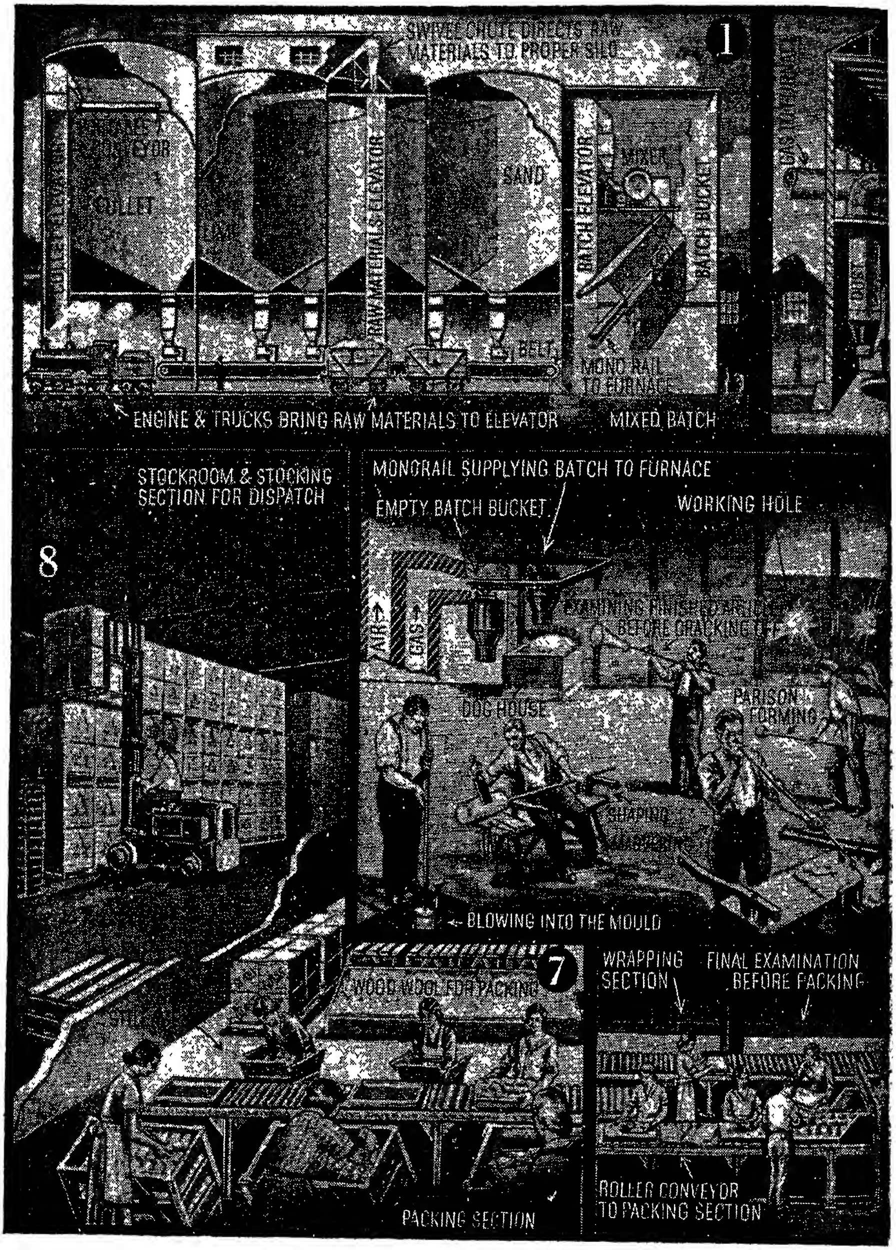
A pot of well-regulated and fined glass is still the first essential in the art of good glass-making. Whereas one furnace of the multi-pot type, for instance, can hold as many colours or grades of glass as there are pots; only one type of glass can be drawn from a tank furnace.

Glass furnace pots are made of hand-picked clays. The clay pot cannot be fired until just before it is to be placed in the furnace to replace a worn-out or defective pot, and is very fragile.

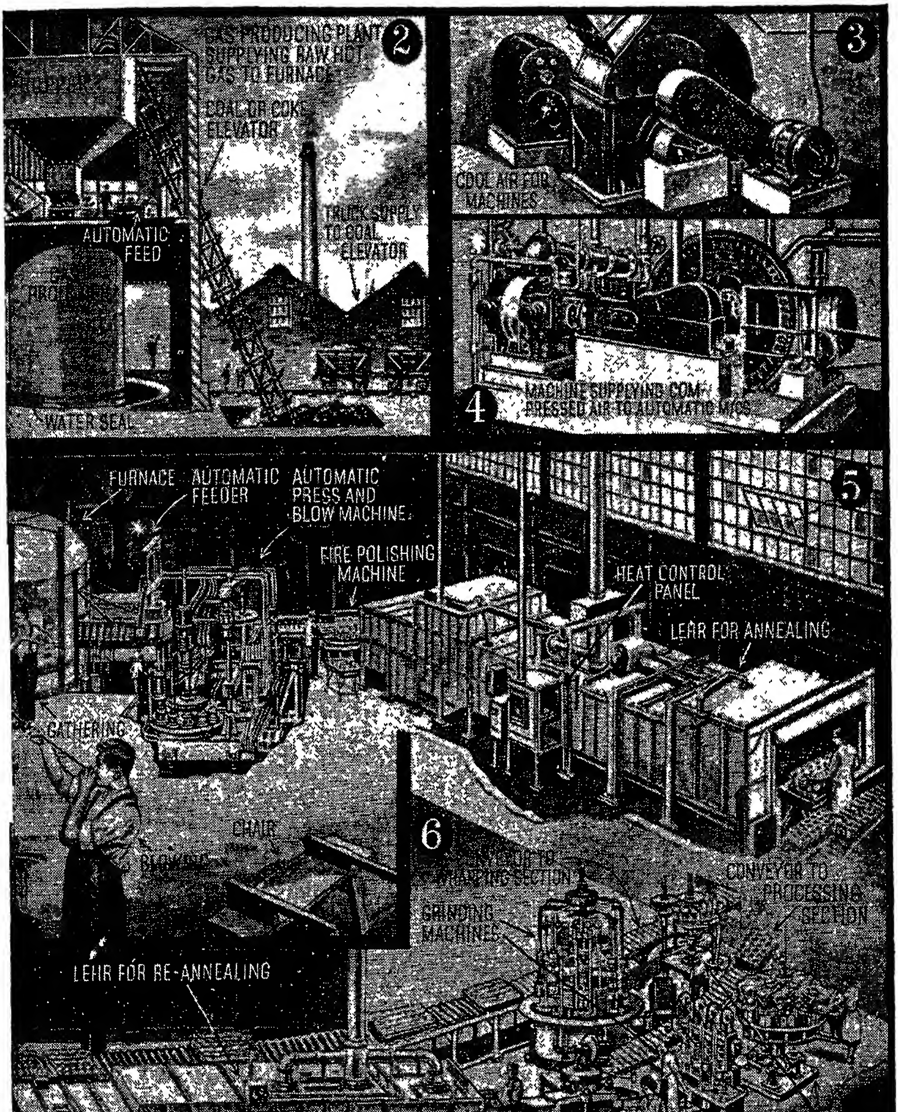
Many types of pots are in use and vary considerably in size at different factories. In section some are round, others egg-shaped, while the "skittle pot" types are small though in appearance not unlike the

BREAKING UP!

FIG. 1. *Breaking up a cold pot of optical glass which has been withdrawn from the furnace. In every other section of the industry, pot breakage is guarded against to avoid loss in output, but in the case of optical glass the pot must be shattered to release the hardened metal as here seen. When exposed, the solid mass of metal is itself broken up into manageable pieces, great care being taken in grading the various lumps for splitting, grinding and polishing, to ensure perfection.*

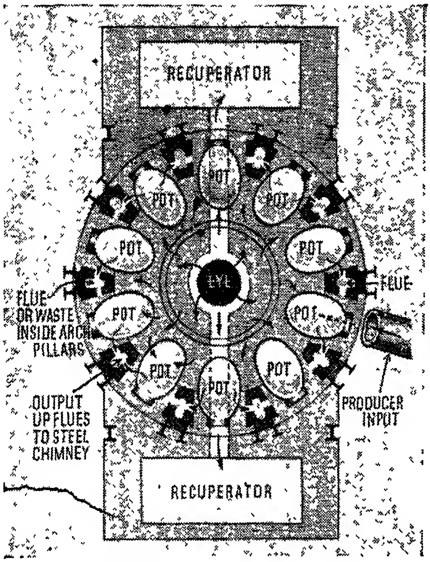


SCENES IN A GLASS WORKS:
FIG. 2. *In successive stages the illustration above shows the production of glass articles from the mixing of the raw materials—principally silica, soda and lime—to the packing and dispatch of the finished articles. Every home owes much of utility and beauty to the skill of the glass-worker, whose traditional craftsmanship has survived the introduction of labour-saving methods.*



TRIUMPH OF ORGANIZED SKILL

Whilst semi-automatic machines which press the molten glass into shape, and fully automatic ones which produce the finished article without being touched by hand, are used for the mass production of cheaper kinds of glassware, the better quality type still depends upon individual skill. Both methods employed may be studied from the above impressica of work in a large glass factory.



INTERIOR OF A GLASS FURNACE

FIG. 3. *Above is seen a plan of the interior of a glass furnace. Clay pots are arranged in a circle, the heat coming in through an "eye."*

jars in which, by an accepted convention, the Forty Thieves met their unpleasant end. Which last remark lends a certain irony to the necessary comment that the working life of all pots varies considerably. Some last as long as six months; others need replacing after a day or so.

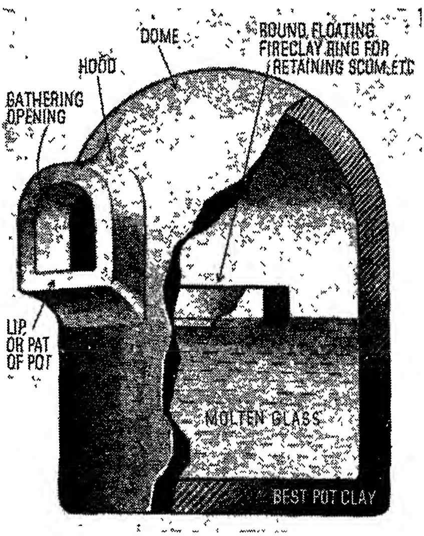
All pots have to undergo a preliminary firing before becoming fit for service in the furnace proper. The "christening" preliminary firing of a pot takes place within an auxiliary furnace; and it is slowly brought up to a heat satisfactorily to withstand the heat of the furnace proper.

The "stage" is now prepared for the "setting" of a new pot. Workmen attack the wall of the actual furnace below the defective pot-mouth, pulling down the bricks and clay mortar with crowbars. As the wall falls, heat gushes out. The old pot is now levered from its seating and pulled out as quickly as possible by means of an iron-pronged trolley. This is a moment of awe-inspiring beauty. The sweat-gleaming bodies of the men take on a satanic aspect as they pull and lever the dazzling, shimmering, whitehot veteran. When the old pot is out the new pot is withdrawn from the auxiliary furnace and is rushed forward on a similar trolley. Men, working in relays, lever the new pot into the position previously occupied by the old.

Some glass-works house as many as eight complete pot-type furnaces with a pot capacity of from four to twelve or more pots per unit furnace.

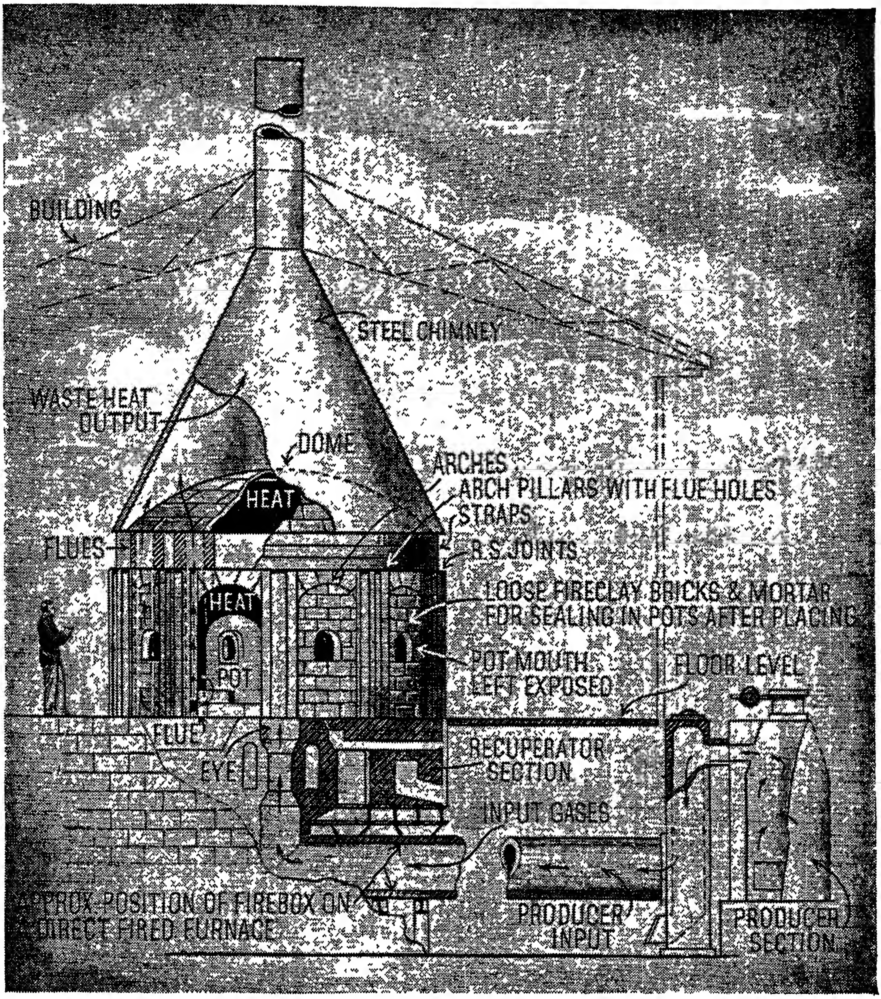
No glass-making plant is complete without a very necessary type of auxiliary furnaces, termed "lehrs" or "annealing" ovens, designed slowly to cool off to room temperature the hot glass as it leaves the glass-makers' hands.

This oven—a tunnel—is of great length, either oil-fired, gas- or coal-fired. The finished wares are placed singly in rows within coupled sheet-iron pans or on steel mesh endless mattresses which run



CONSTRUCTION OF A FURNACE POT

FIG. 4. *Made from specially selected clay suitable to withstand great heat, the furnace pots undergo a slow preliminary heating before being placed in position in the furnace.*



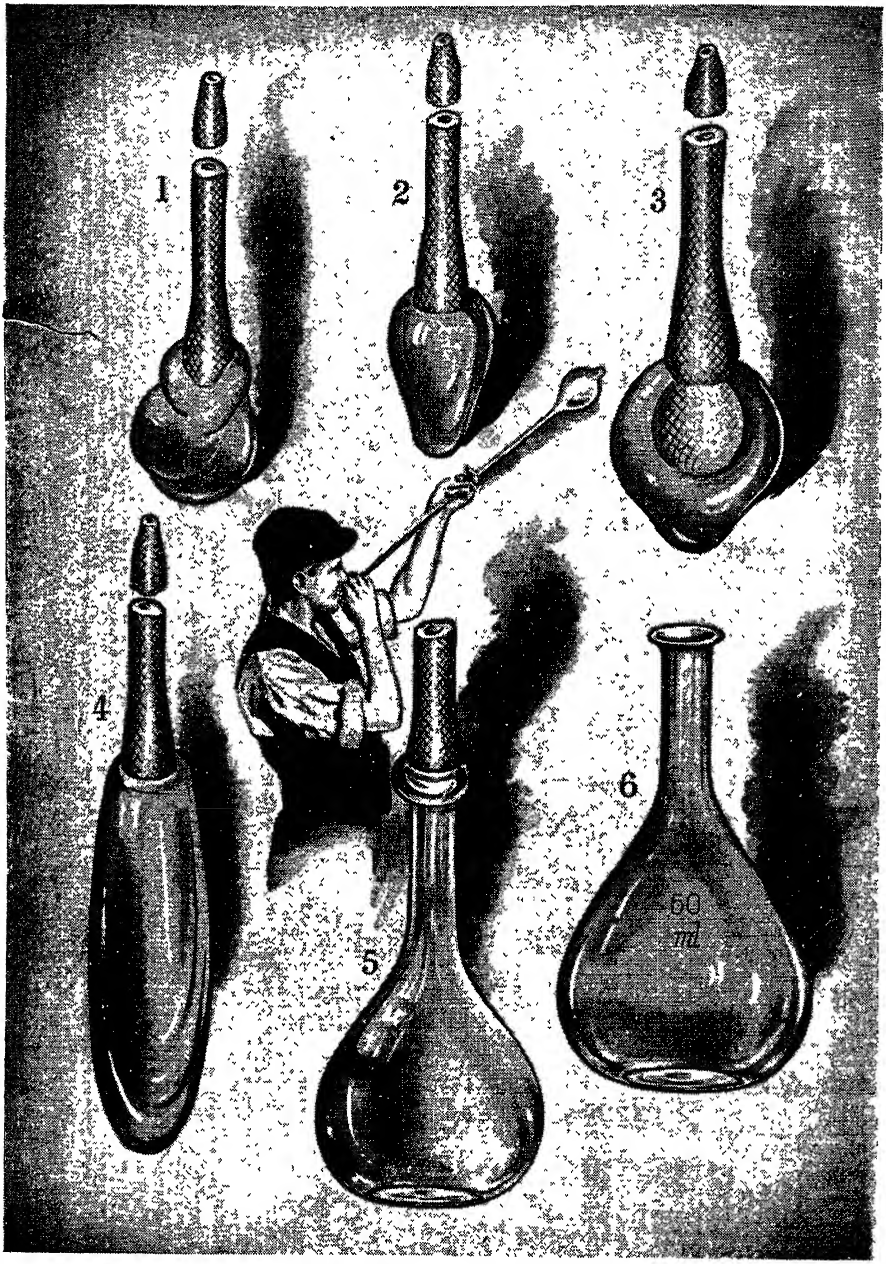
HOW A GLASS FURNACE FUNCTIONS

FIG. 5. *Here in section is seen the glass furnace of which a plan is given on the opposite page. Note the position of the pots, built into the furnace. These pots are of the same type as that also shown opposite; yet another example is in process of being broken up in the illustration on p. 115.*

on bearings down the entire length of the oven.

This action and process of annealing removes "strain" and acclimatizes the glass to the temperature of the outside world as the articles on each tray, or on the belt, are pulled to the receiving end of the tunnel by a youth, at stipulated periods—again see Fig. 2.

In the majority of instances, glass-makers have been initiated to the craft on leaving school. A craftsman skilled in hand-making glass is priceless. In an age of intricate moulds and automatic machinery the race is tending to die out in certain localities. The secret of his skill is the fruit of long practice. As the semi-molten metal is starting to sag upon his



STAGES IN MAKING A FLASK

FIG. 6. *1, gathering molten glass on blowing-iron; 2, parison after marvering; 3, marvered glass "puffed up" by mouth-blowing; 4, elongated parison before insertion into open mould; 5, after withdrawal from mould; 6, finished flask, cracked-off from iron, brimmed and engraved.*

blowing-iron, the worker caresses the glass gently with his tongs, or flattener. When he blows his enormous bubbles, we watch fascinated, expecting a burst or fall as he swings his blowing-iron with the object of elongating the glass (Fig. 2).

Apart from moulds, to be touched upon later, the "hollow-ware" makers use few implements. Let us note that the glass for making bowls, wine-glasses, jugs and decanters, be they plain or intended for cutting, must be of an exceptional quality (that is for "collectors' pieces") most of it being of a "lead crystal" variety. This is a very soft glass for working and remains in that state for a much longer period than say "flint" glass.

Blowing-iron's use

From the earliest period of glass-blowing, the use of the blowing-iron or tube has been the method employed. This pipe is a hollow iron tube, tapered for blowing. The other end is rather bulbous to facilitate "gathering" the glass from the pot. The glass-worker also owns an assortment of tongs and shears, used for flattening, smoothing, and opening out the "parison" or bubble of glass. Many of these implements in use are held against the molten glass, whilst the workman rotates his blowing-iron or "pontil" with the palm of his hand along the arm of his "chair." This consists of a wooden seat for the worker, with two iron-shod arms projecting at a gentle slope (Figs. 2 and 7).

Various shaped blocks of wood or iron —"shaping blocks"—are used to obtain the desired contours of a parison that has been blown on the iron; or the contours may be freely hand-made. The parison blob of hot glass is designed to suit the class of ware being made, a suitable parison being half the battle towards producing a good shape, be it hand-worked or mould manufactured—even on fully automatic bottle-making machines.

To transfer a shape, in order to enable the end attached to the blowing-iron to be opened out, a short iron rod is used, termed a "pontil" or post. Made of solid iron rod, it carries a blunt button end; a small quantity of glass is gathered upon this tip and "stuck" to the glass awaiting transference from the blowing-iron.

Pontil mark's meaning

When fastened to the pontil, the glass is re-heated, being again worked with shears or crimped with tongs to a desired pattern. The reader may own salad bowls or jugs, etc., made in this fashion. If so, an examination of the base centre may reveal a shallow depression that has been ground away. This is a sure indication that the vessel was hand-made and hand-fashioned.

In the old days, many hand-made articles were made from moulds of wood or iron. Simple wooden moulds, which had the disadvantage of soon charring to larger than the desired internal diameter, were fashioned by chiselling out two exact-sized pieces of wood, each being the other's counterpart in design and a hole being made at the top of the two halves for the insertion of the parison of glass. On hinging together the two halves, the mould was complete. The woods used in their construction were alder, poplar, pear and lime. Even to-day wooden moulds are used for certain experimental "short-run" work.

Semi-automatic moulds

When metal moulds became popular, their style remained the same, and at the present time is only a trifle more elaborate for a hand-worked mould.

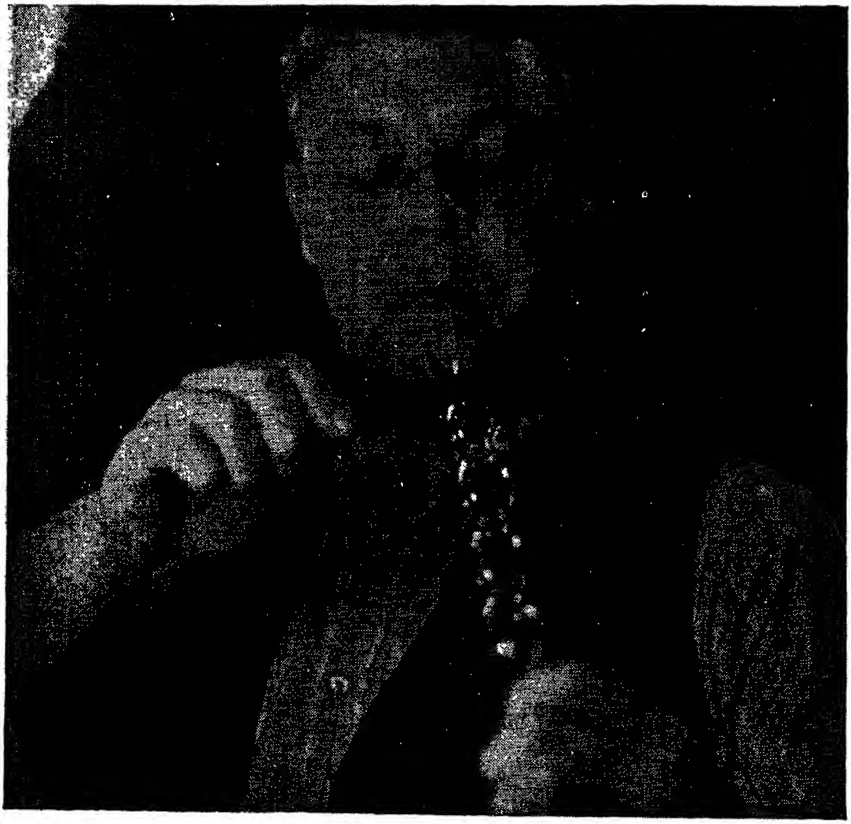
Moulds for semi-automatic and fully-automatic machines are much more elaborate, consisting of a parison mould and a finishing mould (Fig. 9). The parison mould does the work of the glass-blower, forming the special shaped

bubble of glass for insertion into the finishing mould. A jet of compressed air blows up the parison, after its transference, to the shape of the finishing mould's interior (see Fig. 2).

A furnace group of men, working on one individual task is called a "hole" of five men. They are the "gatherer," the "blower" or "marverer," the "finisher" or "chair-worker," the "wetter-off" (usually a youth) and the "taker-in;" this last being the youth who removes the finished article to the lehr, or annealing chamber, to cool off. Promotion mainly takes place from the two last-mentioned ranks of workers.

Behind the wall of the furnace is a molten glass-filled pot waiting to be worked out. The gatherer prepares himself for the task, carefully heats his iron, inserting the gathering end just inside the lip of the working hole of the pot, and supporting the other end upon a rest. Pre-heating guards against "chilled" metal—or disfiguring iron marks showing upon the ware when blown.

On viewing the molten glass, or metal, inside the pot through a piece of blue glass, we see a clay ring floating on the surface of the metal, keeping back any sediment or surface scum from creeping



GLASS AIDS SCIENCE

Glassware is used for many purposes in the laboratory and dispensary. In the above photograph a bench-worker is working on a piece of scientific glassware which has been heated by a blow-lamp. He shows how a gauge may be used in work of this character.

SKILL OF THE CHAIR-WORKER

FIG. 7. *In the above illustration a chair-worker is seen in the act of removing a chair-made, footed glass goblet from the blowing-iron. Subsequently, the ware is brim-finished on a cracking-off and flashing machine thus both improving its appearance and providing a smooth drinking-edge.*

glass works—a fascinating sight!

Watch his motions and face, as he wields his iron, forming as though by magic the shape desired. After years of blowing, a glass-worker's face develops elastic properties. Sometimes we see him make no more than a modest blow to form a parison to be enlarged within a mould. This parison is worked and enlarged to the size required, so as easily to conform to the shape of the mould's interior when actually blown. The blower may then walk over to a mould of the "pull-to" style, let into the shop's floor, or to a mould operated by a wetter-off.

Whether it be a mouth-blown shape or a mould-made article, the resultant glass-ware has to be cracked-off, on withdrawal from the mould.

Chair-worker takes over

Next the chair-worker or "finisher" proceeds to model to a conclusion the article in hand. It is quite surprising to see one of these men, without taking any measurements, shape a group of glasses or vases with no variation to be detected by the naked eye; or to see him welding together intricate specimens of chemical glassware with consummate skill.

The taker-in is always busy removing new creations to the annealing "lehr," as the chair-worker hands over to the wetter-off, to enable the latter to disconnect the finished ware from the iron.

In reviewing independently the most important methods of manufacturing certain articles of glassware, we may as well start with a simple jug and tumbler. These are evolved from a "lead crystal glass," for subsequent brilliant cutting, or etching, or to be left quite plain. For a decoratively cut piece the glass-blower will have to make a much thicker jug or tumbler, to allow for the pattern to be added at a later stage.

Making a jug

A gathering is made from the pot mouth to the required quantity. Assuming that the jug and tumbler are to be of a cylindrical pattern, a pair of moulds is utilized for spun work.

Our glass-blower, having marvered the gathering to a suitable parison for the jug or tumbler, mounts his bench or stool, thus being elevated directly above the mould. Seated beneath him is the assistant awaiting him with open mould.

On the parison being carefully placed within the open mould, the assistant closes the two halves. The glass-blower, exercising his lungs by blowing down the blowing-iron, and at the same time rotating it, produces a shape to conform with the design of the mould's interior. This action of spinning the iron forces the shape of the glass within the mould to rotate, thus eliminating mould joints and producing a flawless skin and finish enhancing the appearance of the article.

On the assistant opening the mould, the shape is found still to be attached to the iron. In the case of the tumbler, the next step is for the wetter-off to crack this bottle-like shape from the parent iron by means of a piece of cold steel or an old file. This has to be done with care to avoid any fracture of the body. So far as we are now concerned, the tumbler is finished, except for annealing and any subsequent treatment found to be necessary in the finishing shops outside the glasshouse proper; but the jug has probably yet to be footed, lipped and fitted with a handle.

Adding the foot

If the jug has to carry a foot, we see during the process of blowing the body another small wooden or iron mould being worked, representing the shape of the foot. Whilst this base is rotating in the mould, a wetter-off with tongs in hand rings it deep near the mould joint for easy cracking-off. Both the base and mould blown body, still attached to their respective irons, are now carried to the furnace hole by their workers, to be reheated at the extremes, and then stuck together.

The iron attached to the body portion—that is, the part to be opened out for lipping—is cracked-off in a circle. The body at the now-cracked-off end is reheated, being handled for this purpose by the iron still fastened to the foot or base, which remains in position until the whole jug is completed.

When the body becomes soft by reheating, the top is opened out by the chair-worker, who cuts the soft glass with shears to the shape of the opening required, thus leaving a crude brim. He then models this extremity into a lip by dexterous touches with tongs.

Next—the handle!

To fit a handle, the gatherer takes a "ponty" or short rod of solid iron with the business end flattened. A gathering of glass is made and marvered into the form of a long narrow cylinder upon the ponty. This is held in a horizontal position across the chair. One end of the cylinder is then allowed to adhere to the jug, as far down

its body as may be necessitated by the particular design. With the shears the chair-worker cuts off sufficient of the glass cylinder to meet his requirements (Fig. 8). He presses this free end into position to form the first joint of the handle and lastly he shapes this crude loop to the designer's pattern, or his own style.

HANDLING

FIG. 8. *Still on its base iron, this jug is receiving its handle in the form of a glass rod, here being cut with shears.*

The final operation is the cracking-off of the base iron from the now-completed jug. On completion the ware is removed as soon as possible to the lehr.

Next, let us glance at pressed glass which takes the form of cheaper table-ware, certain styles of cosmetic and commodity jars, stoppers, wall and pavement lights, railway, road and torch lenses, tiles, and illuminants such as bowls and bracket lights, etc., the recommendation of pressed-ware for certain purposes being its cheapness of manufacture. All the necessary processes are carried out in one operation with an assistant gatherer and a taker-in.

Molten glass is gathered from the furnace, and a portion of the quantity desired cut off with shears into the base of the mould by the presser. This mould base, carrying the exterior design of the article, is fitted into position below a plunger, which is shaped to the interior of the article to be pressed.

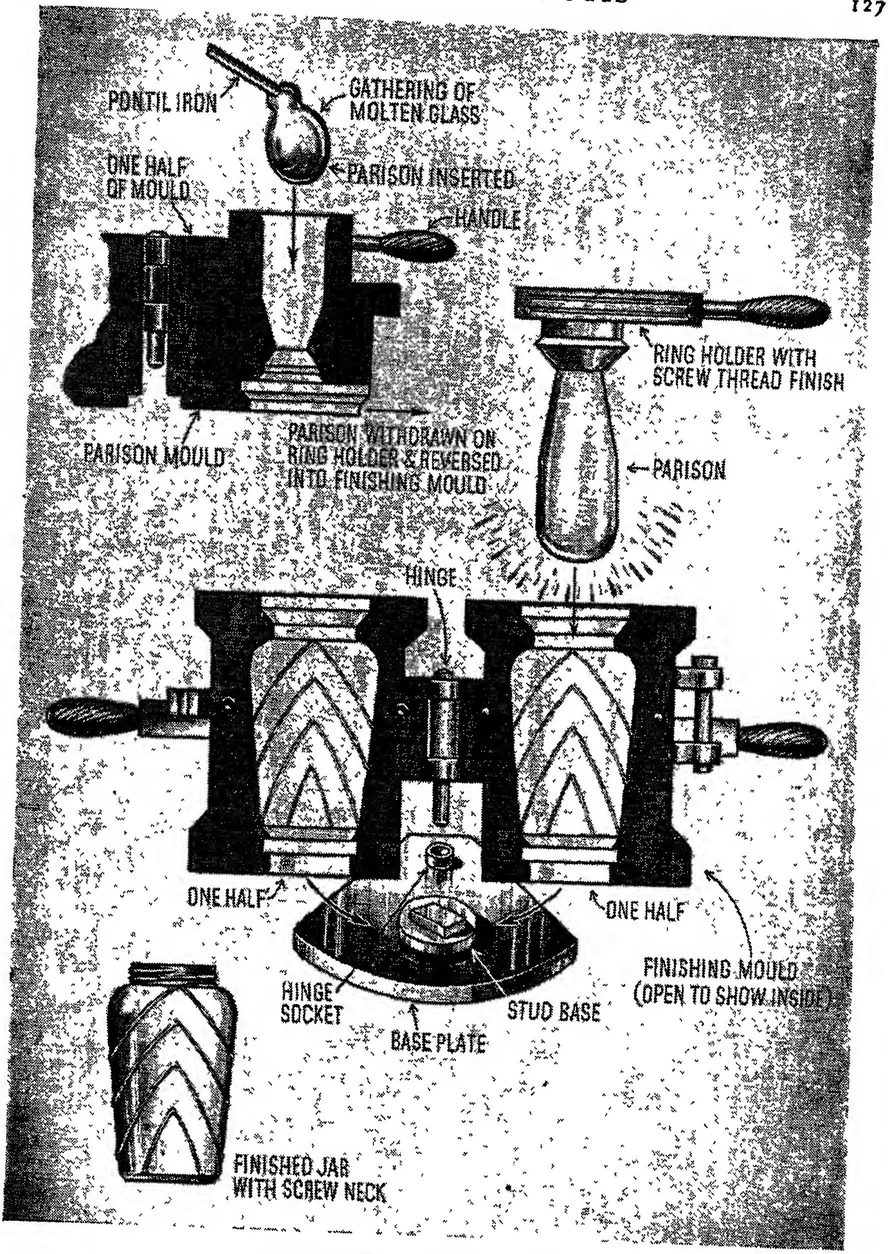
A lever mechanism is connected to the plunger portion, being operated by the workman, who on cutting off the molten glass pulls the lever down with a steady action, thus squeezing the glass into shape.

On the lever being released, the mould is withdrawn, working on slides. The newly-pressed article is removed by inverting the mould and tapping out, or in some cases of very heavy and intricate work by opening the mould by means of the handles provided. The moulds usually employed for pressed-ware are very expensive to manufacture.

Automatic machines play a very important part nowadays in the production of cheap containers for every need. The parison cutter is the chief man on the smaller machines of the "suction and blow" type, or semi-automatic machine. He has to gauge the amount of glass required to form a given article.

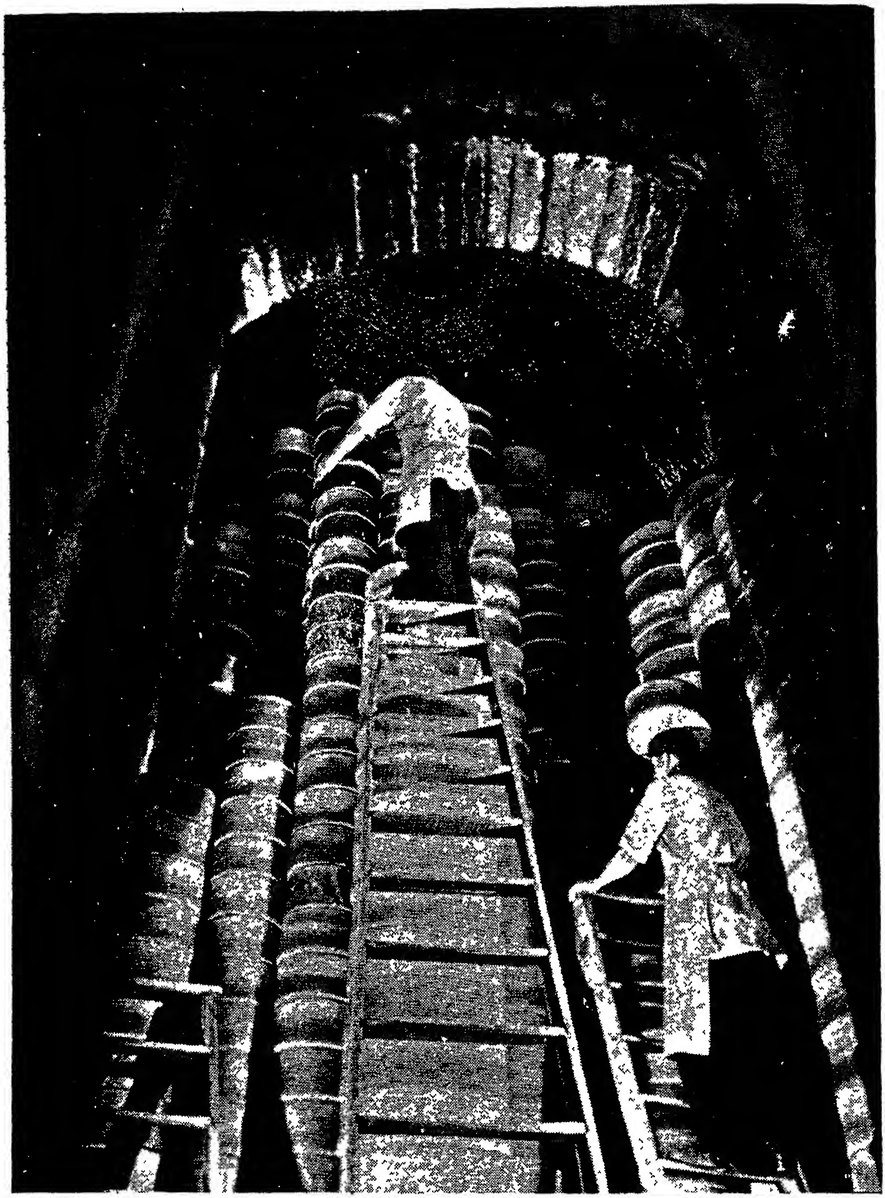
Another method is full automatic working. These machines are quasi-human. They gather the glass, make the parison, blow-up the parison within finishing moulds of great mechanical ingenuity and exactitude, delivering the finished article down to a shute, ready for annealing. All these operations are performed without the article being touched by a single worker.

A wonderful process! All the same let us foster and expand the traditions of fine hand-made glassware. Sooner or later the supreme virtue of all crafts lies in that individual element—the human touch.



MAKING A SCREW-NECKED JAR

FIG. 9. *Stages in the manufacture of a screw-necked glass jar are illustrated above. The globule of semi-molten glass on the gathering iron is precisely shaped in the parison mould, whilst the neck is fashioned by a special fitment and the jar given final shape in a hinged finishing mould. Many articles, both decorative and useful, are made by this process for commercial purposes.*



INSIDE A POTTERY OVEN

Pottery, one of the most ancient crafts, is also one of Britain's most flourishing industries. Above is shown the interior of a pottery oven. Carefully placed in fire-proof boxes called "saggars" to protect them from direct contact with the flames, the articles of pottery ware are carefully stacked and "fired" to produce the hard, porous finish known as "biscuit." After it has been withdrawn from the "biscuit fire" the article is ready for decoration, glazing, and hardening. The same oven, or a similarly constructed one, may be used to fire the glost (or glazed) ware.

HOW THE POTTER WORKS HIS CRAFT TO-DAY

By GORDON M. FORSYTH, R.I., A.R.C.A., AND MOIRA FORSYTH, A.R.C.A., N.R.D.

British pottery a home-grown industry. Tradition plus progress. Stages from raw material to finished product. Use of jolleys and jiggers. Firing and glazing processes explained. How tunnel ovens are operated. Methods of decoration. Transfer printing and other forms of ornament. How your cup and saucer are made.

TEAPOT, cup and saucer, or, if you will, plate, vase or bowl, and any other familiar objects of the many, humble or costly, that we owe to the potter's craft. Let us ask them to tell their own story, of how they come into being and of the workers who make them. The reply would be something like this:

British pottery is essentially a "home-grown" industry. Though in design it has not escaped external influence, practically all the craft's raw materials are found in Britain and both its production and the skill of its workers have resulted from centuries of undisturbed development.

British pottery famous!

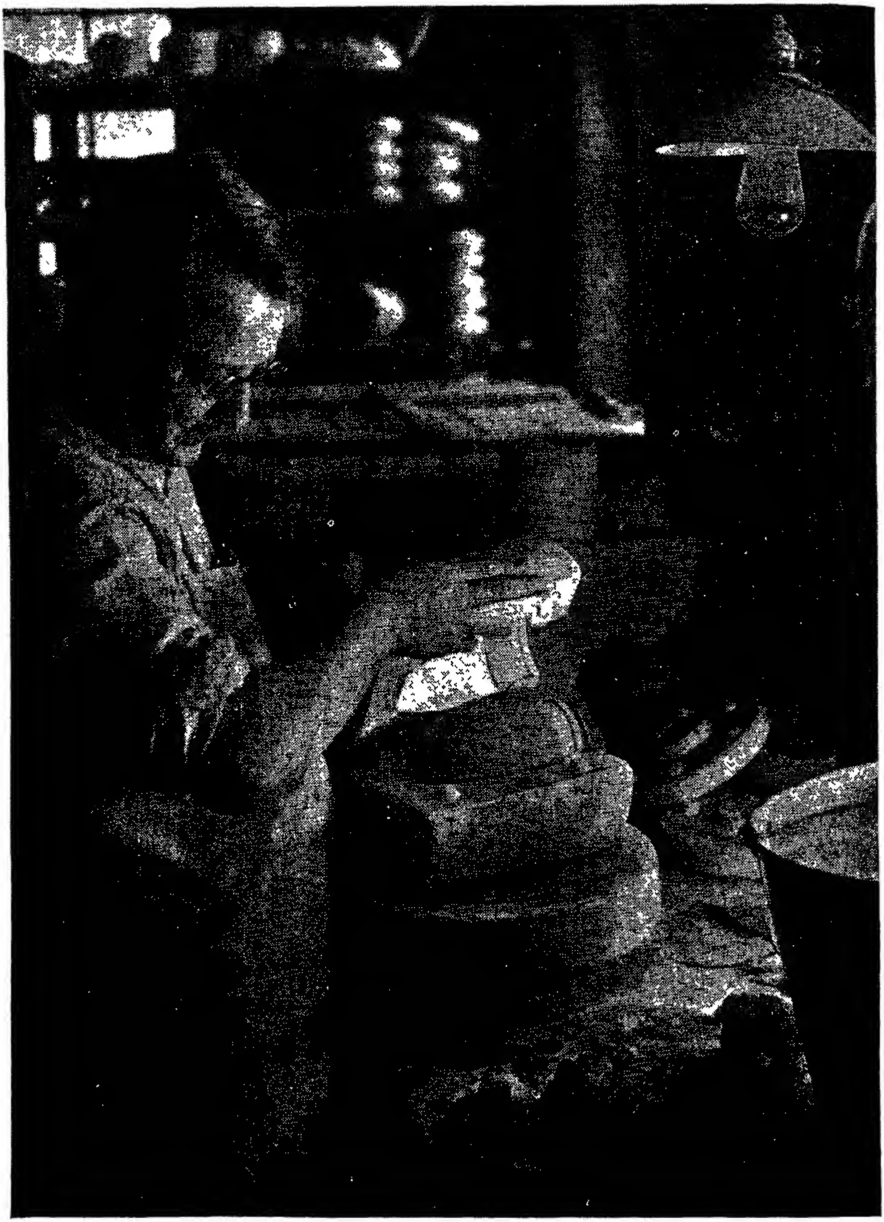
That throughout the world British pottery is famed for its quality is attributable to the fact that, although the industry has developed along mass-production lines, it retains its individuality. Pottery is a fragile material, difficult to handle by machine. Hence mechanization has not been great, and almost every worker, however small his part in the finished product, is a skilled craftsman.

But before tracing the progress of our cup and saucer through a typical (but imaginary) factory, let us briefly glance at the distribution of the industry throughout the United Kingdom.

The manufacture of general earthenware is largely concentrated in the Potteries, as are fine china and English china, though there are famous firms elsewhere including those at Derby and Worcester. 69 per cent. of the tile production of the country is centred in North Staffordshire, and 75 per cent. of electrical porcelain. Sanitary ware is more dispersed than any other section, but at least 50 per cent. of its total production comes from the Potteries.

The natural tendency of the industry to concentrate in one district has had valuable results in the past, and may be of great importance in future development. Although this settlement was originally brought about by the abundance of local clay and coal, the chief locating factor to-day is the skill of the people who have worked in the industry for generations. Ancillary services have grown up round the industry: potters' millers, engaged in the preliminary processing of raw materials; colour manufacturers, preparing underglaze and enamel colours; lithographic transfer firms and engravers, both producing patterns for the mass-decoration of ware; and cratemakers and coopers, whose venerable craft is still of great importance. These are all skilled trades, some of them demanding five to seven years apprenticeship.

Originally, the raw materials of pottery production were drawn from the local soil, and even to-day Etruria marl is used



OPENING A MOULD

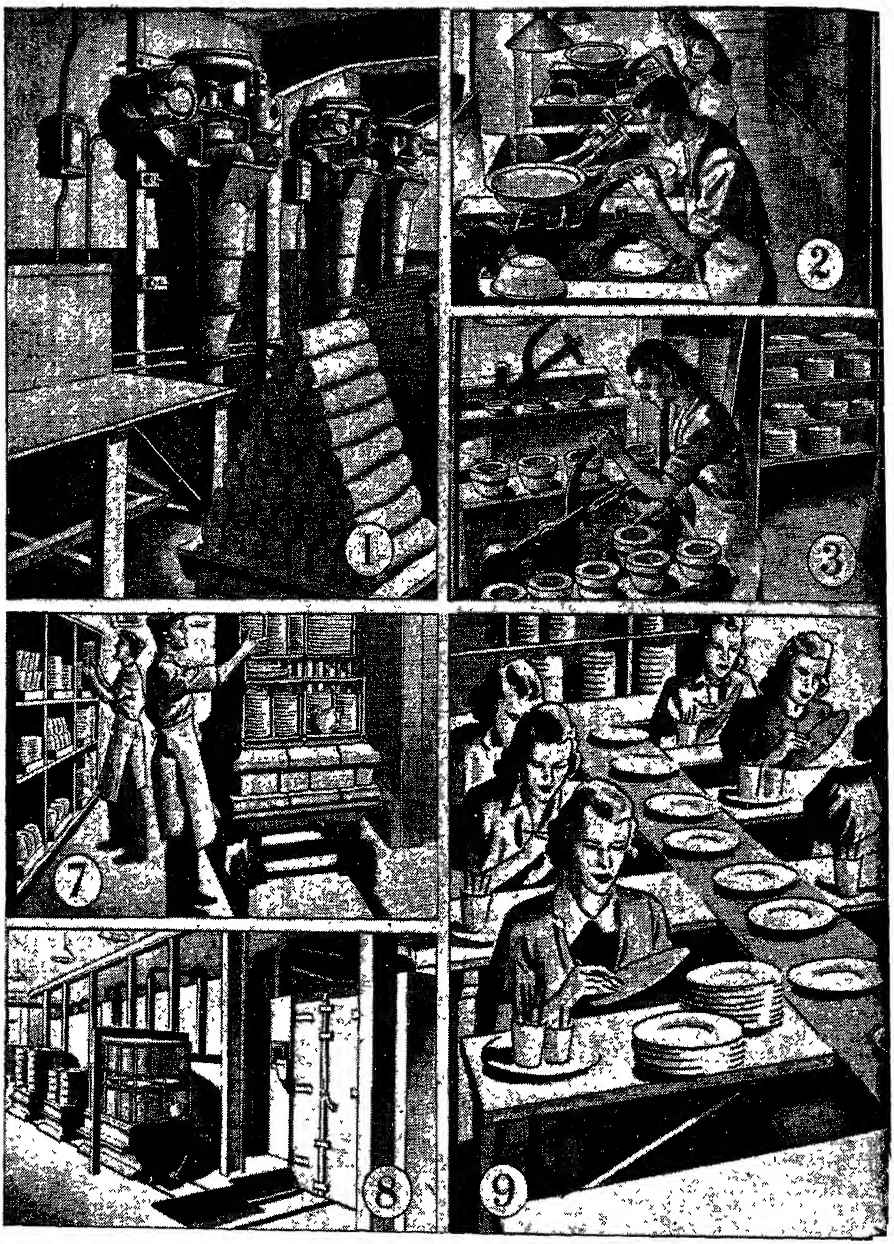
FIG. 1. *Above a skilled craftsman is opening the two-piece plaster mould in which a classical vase has received its form. This method of construction is sharply differentiated from that of throwing on the wheel when, as shown on the opposite page, the rapidly rotating clay is shaped by hand-pressure. In modern production casting is generally used to reproduce pottery sculpture, and is yet another process demanding care and knowledge on the part of the craftsmen concerned.*

MODERN-STYLE "THROWING"

FIG. 2. *One of the potter's most ancient devices, the throwing wheel, when now used, is electrically operated. By means of this rapidly rotating disc, the clay is shaped with an almost incredible speed. Here, the neck of a vase is taking form under the hands of an experienced thrower.*

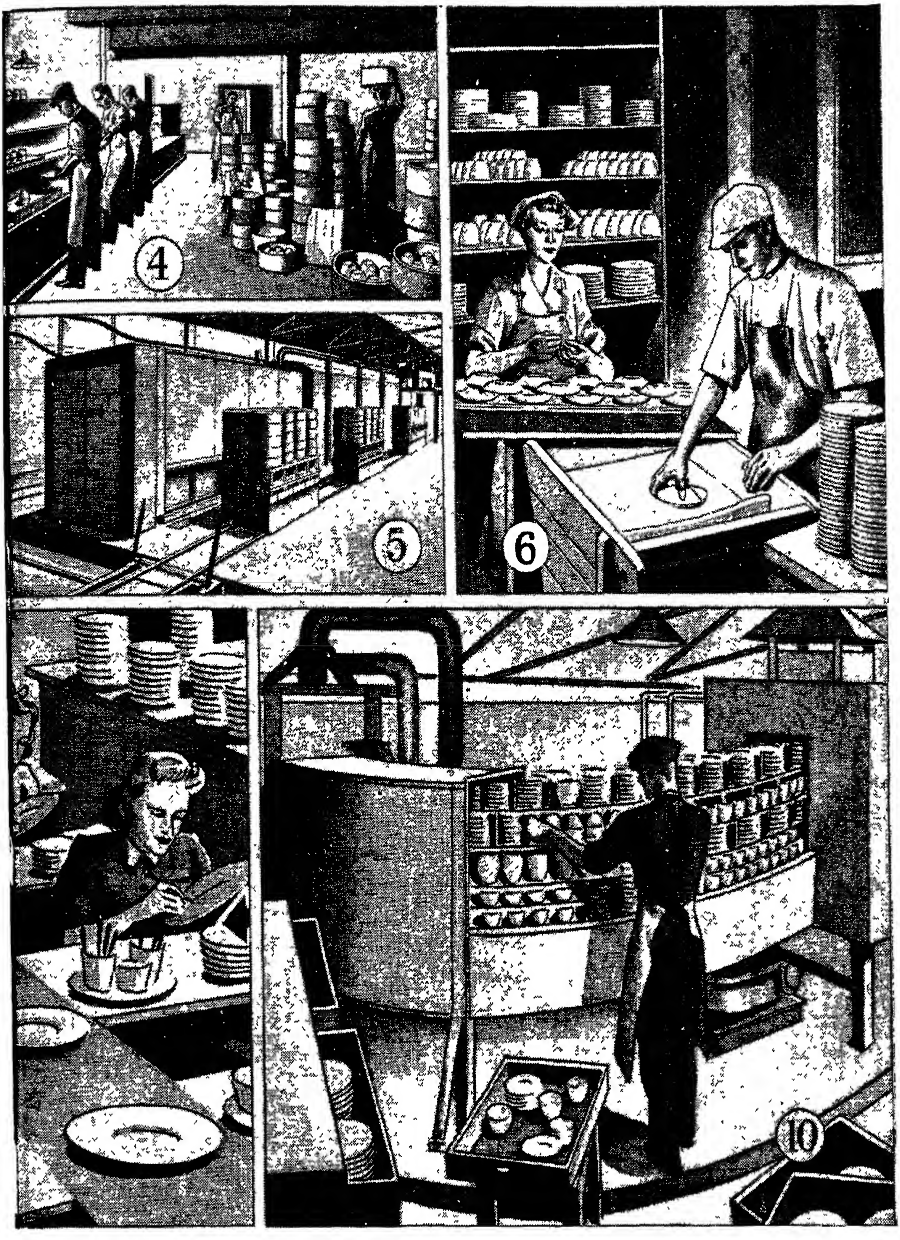
in the Potteries for making the brown teapot and the red flooring tile, as well as for the Staffordshire blue brick and the roofing tile; while local coal is used for firing. The white earthenware clay body is a mixture of ingredients drawn from other districts: ball clay, china clay and Cornish stone from Cornwall, Devon and Dorset, and flint from France or the south coast of England. China ware derives its translucency from the substitution of calcined bone for the flint and ball clay used in earthenware. The chief materials of glaze making are china clay, Cornish stone, flint, felspar, borax, lead silicate, and the various metallic oxides. Many of these raw materials, heavy in bulk and low in money value, travel by canal barge.

Pottery is still made from clay and hardened by fire, as it has been from the earliest days of civilization. The processes of pottery-making in this district have not greatly changed since industrialization was first effected, but the introduction of the continuous firing oven means a change not only in methods of firing but in the general planning of production. When this type of firing is used the layout of the factory must centre on feeding the kiln, and there must be sufficient production to keep it continuously at work. Continuous firing has not yet superseded the older intermittent method, but of recent years numerous "tunnel" ovens have been installed in the large factories. It is difficult to believe that a delicately



PUG-MILL TO ENAMEL KILN:

FIG. 3. *How a modern Pottery functions is indicated in another of the drawings specially made for this book. Seen above are the main processes which are fully explained in the text. The ingenious methods whereby raw material is transformed to many useful and even essential domestic articles preserve in great part their traditional craft-character:* 1, *battery of pug-mills, upright type;*



SCENES IN A POTTERY WORKS

2, power-driven jigger; 3, jolleying cups; 4, placers at work (note fireclay saggars); 5, continuous-firing biscuit kiln; 6, dipping: glazing after biscuit fire; 7, glost placers loading truck; 8, the glost oven; 9, pottery decorators (note conveyor belt); 10, enamel kiln, circular type. How progressive methods and modern appliances expedite production is well seen in these pictures.

glazed and richly decorated teacup and saucer can be evolved from the clay and stones we see weathering in the factory yard, yet every process in their making takes place within the four walls of the average "potbank." Now let us follow the evolution of our teacup.

Making a teacup

The first stage is the preparation of the clay body. This is a process of purification and mixing, largely carried out by machinery. The component parts of the earthenware body are as follows: china clay 20, Cornish stone 15, calcined flint 35, ball clay 30. Roughly we may say that the china clay gives whiteness, the stone and flint hardness and durability, and the ball clay the plasticity necessary for easy working.

The china clay, Cornish stone, and flint are separately ground in water in great milling beds, while the ball clay passes through a "blunger" containing a series of revolving blades. The various materials are mixed together in their due proportions in the slip state, i.e., in liquid condition, passed through sieves, and then over a battery of magnets to extract any minute particle of iron which may be in the mixture, and which, if allowed to pass, would cause a speck or defect in the ware. Thereafter the slip is pumped into a series of press-cloths—oblong bags made of sail-cloth—and the water squeezed out by the pressure of the pump. The presses are then unscrewed one by one and the cloth bags emptied. The residue of clay is rolled up, looking very like rolls of thick blankets with a corrugated surface. From the mill this clay is taken to the pug-mill and thoroughly "pugged." The pug-mill is a kind of mincing machine, in which a series of revolving blades mix and knead the clay, which is slowly pushed out of the pug in a long cylindrical or oblong mass, as is seen in Fig. 3.

The clay is carried straight to the making shops, but may be stored in damp-boxes or clay cellars before it is used, in which event it must be "wedged" by hand, as clay very quickly begins to dry on surfaces exposed to the air, and must be made thoroughly homogeneous to ensure success in the using.

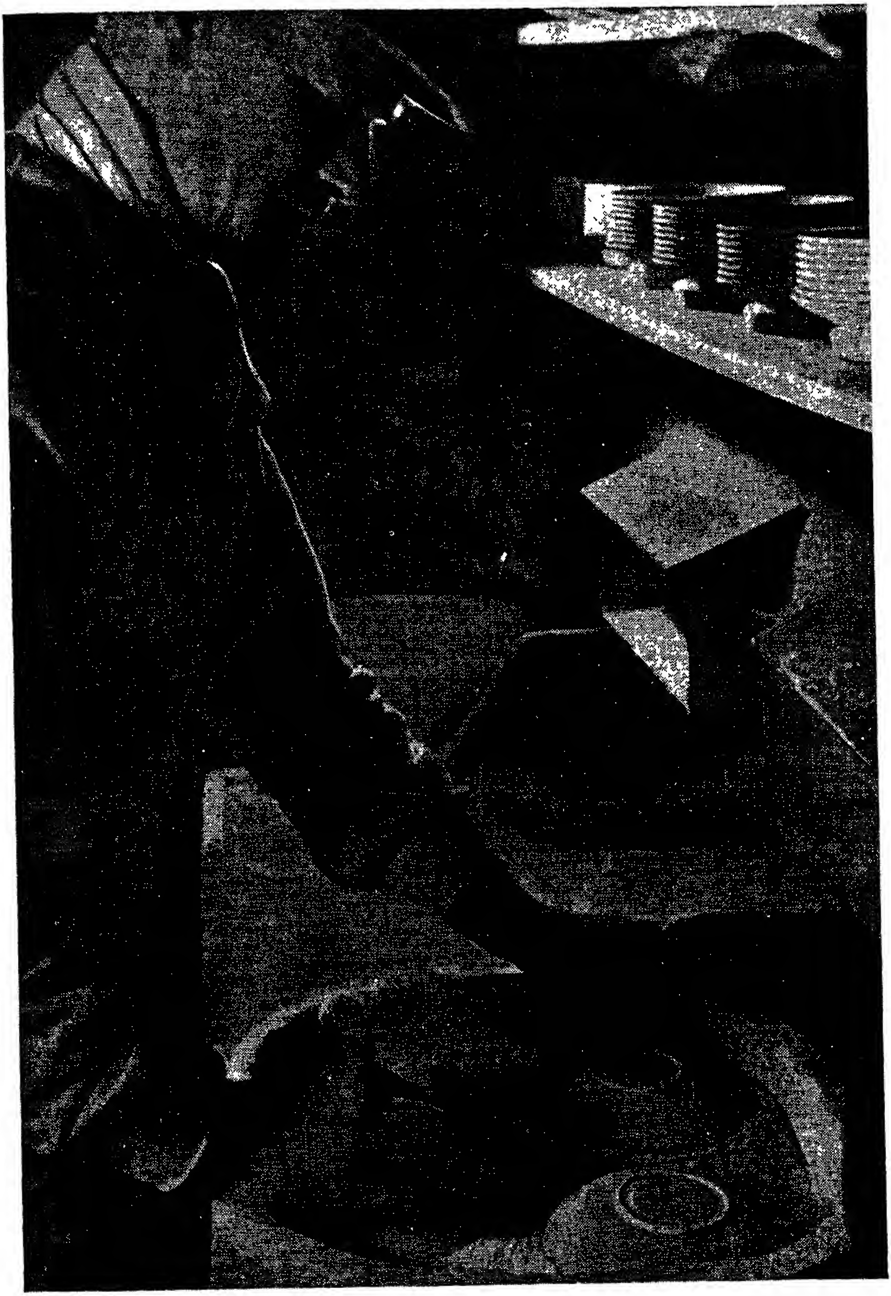
In modern production, the potter's wheel is now rarely used (Fig. 2); its place has been taken by the semi-automatic throwing machine known as a "jolley." This has a power-driven revolving disc with a head like a metal plant-pot, which holds a plaster mould; a ball of clay is placed inside, a lever pulls down a metal template into the revolving mould, and in an instant spreads the clay over the whole surface (Fig. 3). After this, any spare clay is cut away from the edge, and the mould containing the shaped piece carried away to the drying cupboard.

Flat pieces, such as saucers and plates, are made on a bench "jigger" by much the same process, but here an automatic spreader is first used to make a pancake of clay of the required size. This is lifted and placed on the mould, and a steel template drawn down to form the outside of the piece and give it a rim or foot. Large flat dishes are often made in the same way, and finished by sponges and rubbers. This is a highly skilled operation, as interesting to watch as the evolution of a shape in the hands of a thrower, especially in the making of large elliptical or irregular-shaped dishes.

Passed to the handler

Instead of making on the jolley and jigger, pieces may be slip-cast in dry plaster moulds (Fig. 1). This is more usual in large factories making earthenware and china. Casting is the chief method of reproducing pottery sculpture.

Now the piece of clay, whose fortunes we are following, bears a rudimentary resemblance to a cup, but has as yet no



HOW CHINA IS BEDDED

With skilled touch, an operative is bedding china dishes in alumina to prevent them warping in the biscuit fire. The delicacy of china, as opposed to earthenware, necessitates this process.

APPLYING "SPRIGGED" ORNAMENT

FIG. 4. *In some cases, clay decoration is applied to the body of vases or other objects. How such ornament is made by pressing clay into specially designed moulds is clearly seen in the above photograph. Such ornament is attached with a little slip and the vase goes to the drying room.*

handle, and is rather clumsy. When it has dried to a "cheese-hard" condition, it may be given lightness and finish by a process of turning on a lathe; the cup is refined by the cutting away of surplus clay and the shaping of the foot with a steel tool. From the turner the cup is passed to the handler. The handle has been pressed or cast in a mould, and allowed to dry to the same extent as the cup, to which it is now attached with a little slip. Any clay decoration, such as sprigging, is also added at this stage (Fig. 4). Our cup, with many others, is then carried away on a board to the drying room, where it becomes white hard. In this condition the ware is very brittle and easily broken, and needs most careful handling. Hence, "white hard" is a relative term, as a basic fragility has still to be overcome.

The nature of the clay is changed by passing through its first (biscuit) fire, and it becomes a hard but porous material, known to the potter as "biscuit." If the firing is done in an intermittent oven, the ware is carefully stacked by the placer in fireproof boxes known as "saggars" (safeguards), in order to protect it from direct contact with the flames. Saggar upon saggar is then piled up in the huge bottle-necked oven for firing. An experienced placer knows the various rings or zones of fire which develop different intensities of heat, and places his different wares accordingly. When the oven is stacked from floor to ceiling, its entrance is bricked up and sealed, and the fireman takes over. He, again, is a highly skilled man, knowing the vagaries of each oven, when the heat must be brought up, and how long an even temperature must be maintained in order to give the ware a good "soaking" fire before the oven is allowed to cool. For biscuit the maximum temperature ranges from 1,000 deg. C. to 1,300 deg. C. Tests are taken from time to time during the firing.

Ware cannot be withdrawn until it is cold, and the kiln must cool very slowly. To fill, fire, cool, and "draw" a biscuit oven takes some ten days. At one time placers and firemen were paid only on ware "good from oven," but this method of assessing payment is now abolished.

Through the tunnel oven

Should our cup pass through a continuous-firing kiln it has a different experience. These "tunnel" ovens are long, low structures, built within the main shop. Ware is not enclosed in saggars, but stacked on trucks which are drawn very slowly through a gradually increasing temperature to the required maximum, and is gradually passed on through the cooling stages, to emerge at the other end (Fig. 3). Time of firing varies according to the nature of the ware. A biscuit truck may take from 60 to 70 hours to pass through the oven.

On emerging from the biscuit fire the cup is ready for decoration with underglaze colours. Perhaps the ornament is applied freehand by a skilful pottery paintress (Fig. 7); perhaps a transfer from an engraved copper plate may be applied, such as the familiar blue Willow Pattern. A print is taken from the copper plate in precisely the same way as an etching (Fig. 5) and vigorously scrubbed on to the absorbent biscuit with stiff brushes. The piece of ware is then dipped in a tub of water to wash the paper away, and the sticky oily colour is left on the surface of the piece. This oiliness must be burned out in a "hardening-on" kiln before the ware is taken to the dipping-house to be glazed.

How glazing is done

Next comes glazing. The porous biscuit body readily absorbs the liquid glaze, which is applied by dipping or spraying, leaving a thick powdery coating adhering to the surface (see Fig. 6). By either process this is an operation demanding skill in handling and in the determination of the amount of glaze required. The glost fire fuses the glaze to a glassy film at a given temperature (1,100 deg. C. to 1,350 deg. C.). The placing of ware for the glost fire is a most delicate process; it must be handled with extreme care, and propped on small stilts and spurs to prevent adhesion when the glaze reaches melting point. These stilts are knocked off after firing, and the roughness they leave removed by polishing.

The cup may now be finished, but should it require any on-glaze decoration, whether by lithographic print, enamel colour, gold, silver or lustre, this is now applied and a final firing given in the enamel kiln, at a temperature varying between 600 deg. and 950 deg. Centigrade.

To follow our cup from the factory to

the china department of the big store, where it first attracted our attention, is hardly necessary. Our teacup has reached us as a result of the work of countless men and women whose co-operation, direct or indirect, brings us the thing we want, when and where we want it.

It was not until the last half of the eighteenth century, the days of the first Josiah Wedgwood, that the industry as we know it to-day was established. The growing popularity of tea in this country led to a great demand for the fine tableware which Wedgwood, Spode, and other potters were making, and gave new prosperity to the industry. The tea-cup, whose evolution we have followed, was made in much the same way then as now. That the technical quality of British pottery has remained high from that day to this is largely due to the fine standards set up and maintained by the great traditional firms whose names and fine quality workmanship are familiar all over the world.

Earthenware and china—spectacular sections of the industry—are still of primary importance, but other branches have developed rapidly of recent years, and have an assured future. These are the pottery trades associated more closely with building, namely—sanitary ware, tiles, and electrical porcelain. From the luxurious, coloured bathroom suite to the most delicately precise piece of electrical porcelain engineering, the pottery industry can supply all demands. Electrical

TRANSFER PRINTING IN PROGRESS

FIG. 5. *One of the most usual forms of decoration, such as is so often seen on Willow Pattern plates, is effected by transfer printing. A print taken from a copper plate is scrubbed on to the absorbent ware and the paper washed away leaving the oily colour on the surface of the biscuit.*

GLAZING BY DIPPING

FIG. 6. *Above, the porous biscuit body is being glazed by dipping, after which it goes to the glost fire where the glaze is fused to the familiar glassy film. Dipping requires much skill and judgment as to the amount of glaze to be applied to the work in the biscuit state.*

porcelain, the most modern section of the industry, is highly mechanized, and employs only skilled workers. The sanitary trade calls for a precise degree of skill, and wages in this section are relatively high. This is one of the few pottery trades where women are not generally employed.

An industry so long established has the advantages of long tradition and an almost hereditary craftsmanship to its credit; it also has other legacies in the shape of old and inconvenient factories and lack of modern amenities. Many potteries are very old, and have grown up in oddly assorted units, but year by year new factories begin to take their place, and many more are planned. Some will deplore the passing of the old coal-fired oven, and the two-storied shops with their outside staircases; workers who have been moved into new, light, and well-designed factories, have often bitterly lamented the "cosy" little shops where they used to work. But the change-over is inevitable, and the reconstruction plans of many pottery-making firms include extensive re-building.

Women of the Potteries

Even after marriage, the women of the Potteries have always worked in the industry. Wages are not high, but it is difficult to make comparison with those of other industries, for about 85 per cent. of wages is paid on piece-work rates. This method of payment has long been

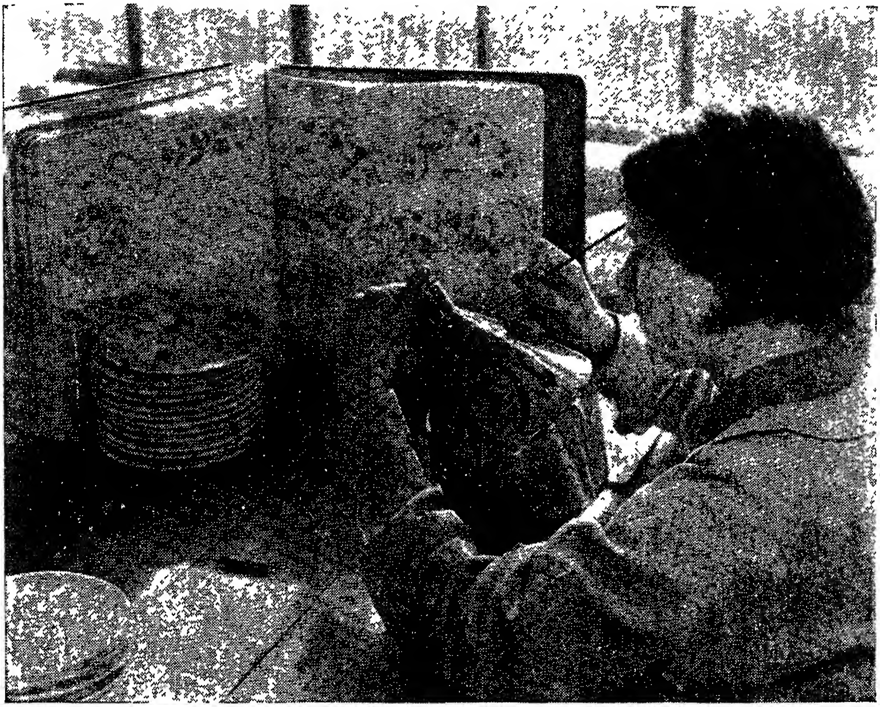
customary with pottery workers. Craftsmen have always been trained within the industry. Young entrants may pass through the Junior Art or Junior Technical Departments of the Stoke-on-Trent Schools. Both provide a two years' full-time course of general and vocational training, which may be supplemented by later specialization in the art or technical side of pottery. The aim of these courses is to raise the general standard of education for apprentices to skilled branches of the industry.

It has been said that the art of the potter cannot survive industrialism. This is but partially true; the personal quality which was so apparent in the work of early Staffordshire potters, and which resulted from the direct expression of the artist's ideas through the work of his hands, has largely disappeared with the introduction of the machine and the division of labour. The industrial craftsman, however small his share in the finished product, still retains an artist's skill, though he has been robbed of his power to create. The mistake which mass-producers in many industries have made too often in the past is to think that "art" can be added to a product by the application of a little ornament. The designer of the future will be given a more important place in industry; he must be trained not as a decorator only, but to understand all the technical processes of industry. He may use the machine as a tool, and still produce a work of art, provided he understands and appreciates the nature of the material he is shaping.

CUPS IN THE MAKING

On the conveyor belt, cups fresh from the jolley and now in process of receiving their handles are on their way to the drying room and thence to the biscuit kiln.

He may well take a pride in his work. Just as potting is among the most ancient forms of culture, so does it continue to survive the assaults of time and man. That in one sense pottery is among the least destructible things is freely acknowledged. Even though an individual pot be broken, its shards survive to tell distant generations of the manner of man that made it. Here, however, it is with potting as a living industry that we are concerned, and as for the future, adequate provision must be made for all members of the public; a new home should at least mean a new tea-set.

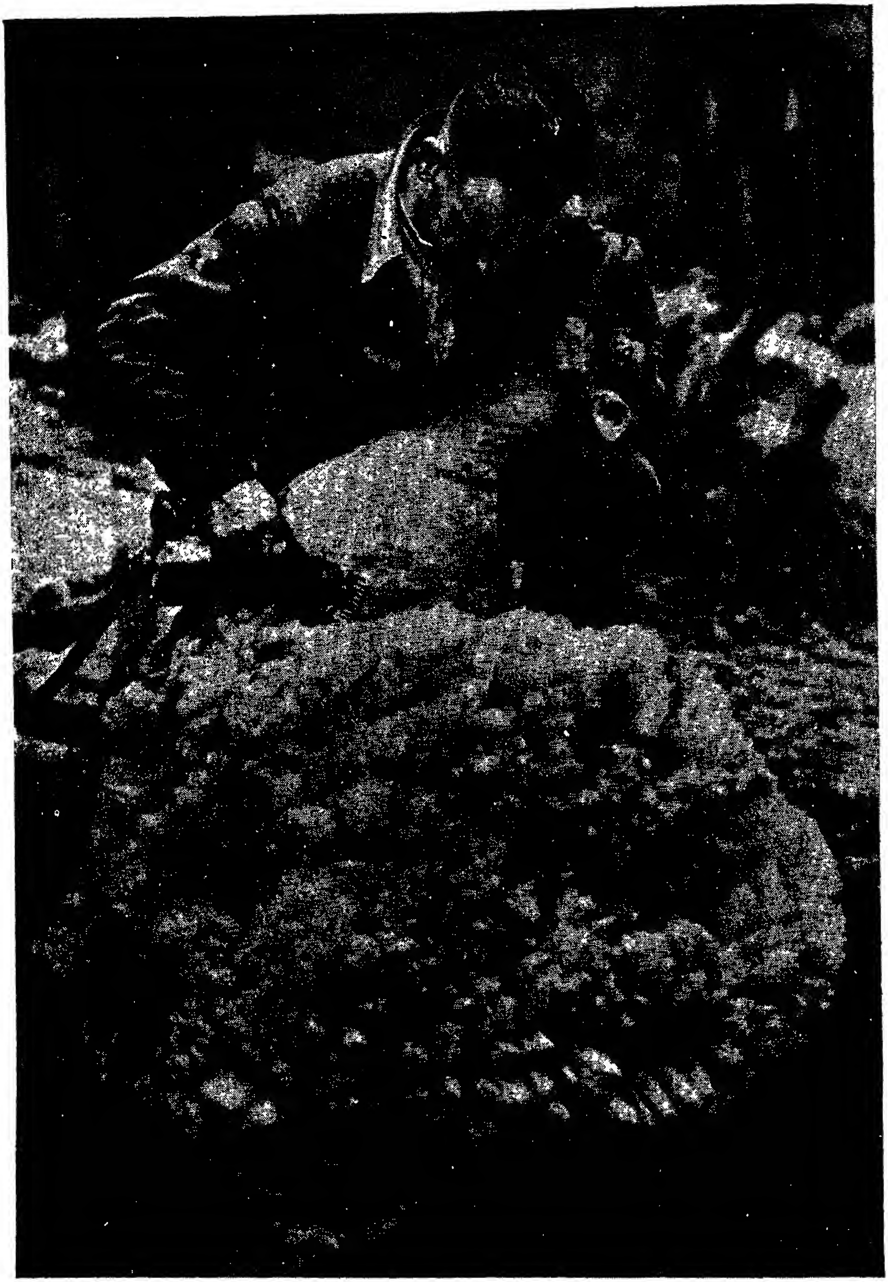


WITH DEFT BRUSH STROKES

FIG. 7. *Deftness of touch is characteristic of the craft, as is seen above where a decorator is completing a design with skilful brush strokes. Open on the bench before her is an old pattern book, still valuable after generations of use. By such means are tradition and progress united.*

The pre-war structure of the industry was that of a loosely-associated collection of individual units, each of which produced and marketed its own wares. Only the large mass-production firms had standardized their wares to any extent; the small firm, with very little mechanization or other restrictive factor, could produce an astonishing variety of shapes, sizes and decorations, and could meet the requirements of any market. War conditions imposed an absolute Government control, standardization of products, pooled production, and selected markets. Small firms became anxious about their future; they contended that control of this kind operates to the advantage of the large mass-producer, to whom standardization is a necessity, and to the detriment of the small firm whose initiative and variety are its chief assets.

The pottery industry cannot be planned simply as a self-contained unit; its prosperity is, like that of other industries, largely dependent on economic factors beyond the control of any single section of the community. But its assets are great: a tradition of quality which has made it world-famous, skilled workers unmatched in any other country, and materials which offer endless possibilities. Improvement in both the technical and the artistic side of production will go on, and given the right soil for development, namely, peace and full employment, the future of the pottery industry will undoubtedly be one of great and increasing achievement for the general welfare of mankind.



FIRST STAGE

Wool from millions of sheep goes each year to make the woollen fabrics woven in British mills. Most of it is imported from Australia and elsewhere, but above is shown a British shearer using a portable shearing machine with almost incredible rapidity to remove a sheep's heavy fleece.

WOOL FROM FLEECE TO FABRIC

By A. N. SHIMMIN AND A. JOHNSON (UNIVERSITY OF LEEDS)

How raw wool is sheared and baled. Choosing and valuing the fleeces. Distribution and size of the woollen industry in Great Britain. Opening and carding operations. Miracle of the spinning mule. How mill operatives perform their different tasks. Dyeing, finishing and marketing the cloth. Sorting for worsted and how it is made.

SEEN on a sheep's back, wool in its natural condition scarcely suggests its latent possibilities. That is, to Mr. Smith, the layman; to Mr. Smith, the expert, it looks very different. He sees beyond the greasy, tangled mass to a wide range of useful and attractive fabrics. He knows, too, that in quality there is every degree of fineness from the coarse wools that go to make carpets to the superfine types from which the daintiest of fabrics can be woven. This large selection of types is not solely produced by the sheep of Great Britain. By far the greater part of the material used in the wool textile industry is imported. From the extensive Australian sheep stations, carrying well over one hundred million sheep, we get large supplies of high-grade wool of the kind which occurs in the fleece of the merino sheep. From New Zealand and South America (Argentina and Uruguay) we get mainly the coarser wool of the "crossbred" sheep. From South Africa finer wool is obtained, some of it vying in quality with the good Australian types.

Although very substantial amounts of wool come from these four primary markets there is not sufficient to permit of making every wool fabric from new wool. It has been said that if everything had to be made of new raw material none of us could enjoy a new suit more frequently than once in five years. This may be merely a pleasing story, but it calls attention to the importance of re-worked materials in wool textile manufacture. From "hard" rags, like tailors' clippings, "mungo" is made; from "soft" rags, like old stockings, "shoddy" is made by the tearing or grinding action of an array of teeth on the swiftly running cylinder of a rag-grinding machine. The origin of the terms shoddy and mungo is obscure. Unfortunately they suggest an inferiority in the final product. When re-worked with a proportion of new wool, or with cotton, these "pulled" rags can put cheaper but reliable cloths within the reach of millions of purchasers.

Centres of the industry

In the west of England and south of Scotland there are old-established centres of manufacture, and cloths of high repute are still made there. It is in the West Riding of Yorkshire, however, that the main concentration of wool manufacture is found. Within a radius of twenty miles from Bradford are eighty per cent. of the workers employed in the industry. Doubtless this marked localization is due to an early use of hill pasturage for sheep, the coal mines of the area for power, and the availability of water power whence the traditional woollen mill derived. Also, in Yorkshire and Lancashire the population is as closely grouped as in any area of

Great Britain, providing a valuable local market for the textile industry.

Specialization in the site of manufacture is matched by specialization in products. Most people speak of cloth made from wool as "woollen" cloth, but the sensitive ear of the man in the industry demands a careful distinction between "woollen" and "worsted" cloths. Serges, tweeds, flannels, and blankets are typical "woollen" cloths. Worsted goods—the term "worsted" originated from the Norfolk town of that name—are the fine-textured, smooth-surfaced fabrics we know as ladies' dress goods and men's wear. Woollen mills are found chiefly in Huddersfield, Leeds, Dewsbury, Batley and Morley districts. Women's dress goods come from Bradford and Halifax, and the finer qualities of cloth for men's wear from Huddersfield. The West of England trade is chiefly in high-grade worsteds, and the Scottish is based on tweeds. Blankets are made in the Dewsbury area, and carpets in the Halifax district.

This list is not exhaustive and obviously omits an important use of wool in the making of hosiery products in the Midlands. It serves, however, to indicate the grouping of wool textile effort—a grouping that contains an extremely interesting range of business endeavour. "Big business" so readily claims public attention that we are apt to think of all industries as collections of large and powerful firms with a few smaller ones filling in the gaps. In wool textile manufacture are some large unit businesses and combines, but most frequent are firms of quite modest dimensions.

Originally the industry was of the "domestic" pattern, run in the homes of the people with hand labour as the driving force. When power-driven machinery took the industry from homes to factories, the family type of business persisted and many firms have preserved the family control for generations, resisting the temptation to be floated as part of large joint-stock enterprises. By the use of the "room-and-power" system in the mills a man may begin, and maintain, a small business on quite a limited amount of capital. From a room-and-power company, which owns a building and supplies power from the engine-house, he can rent space or "room" and the power to drive his small group of machines—usually in a partitioned section of the mill. If, then, he takes work on a commission basis, the money he needs for operating his concern is still further limited. Many firms have begun in this way, and even when they have migrated to mills of their own, the strongly individualistic character of the enterprise has persisted.

Individual judgment needed

Medium scale business has been reinforced by economic doctrine. It has been jested that the West Riding is the real home of the "Manchester School" of private enterprise and free competition. Certainly, there has been every encouragement for the small trader and industrialist to "make a go of it"; and this throng of separate firms is unconvinced that big, rationalized businesses can produce wool goods more economically than the small man. We should remember, also, that the very nature of the raw material imposes upon its users the repeated use of individual judgment. From a fleece full of grease and sandy dirt there must be won the clean-scoured wool that goes to make yarns and fabrics. Estimating the "clean-scoured yield" of a mass of greasy wool is done by individual examination. No man cares to trust another's estimate; he likes to see for himself, because the accuracy of the assessment determines the price he can afford to pay for the wool. It is not surprising, therefore, that the reliance upon personal judgment in valuing raw wool should run through spinning and manufacturing efforts as well.

VALUING RAW WOOL

FIG. 1. *London is the greatest centre of the wool industry in normal times, many thousand bales of wool being imported during each year. Above is seen the valuing of wool at an auction conducted at one of the wool floors of the London Dock, where such sales are regularly attended by buyers.*

From this brief review of the structure and distribution of the industry in Great Britain we turn to the more technical aspects of wool textile production.

From sheep to mill

The fleeces shorn from the sheep itself during the wool season (during June and July) are packed in their greasy condition by power-presses into bales weighing about three cwt. each. These are shipped to London where the Port Authority can store thousands of them, to be cut open and, if not previously done, inspected.

On arrival at the mill the wool may be converted into woollen or worsted yarn and cloth, according to the fibre.

In woollen spinning, the hand spinning method is imitated, but worsted spinning conforms to modern ideas of production. The choice of method depends to a large extent upon the character of the wool fibres whose most important spinning properties, length and fineness, vary greatly even in fibres from the same sheep. Woollen machinery is designed to deal with fibres differing in length and fineness, whereas worsted machinery demands careful selection or "sorting."

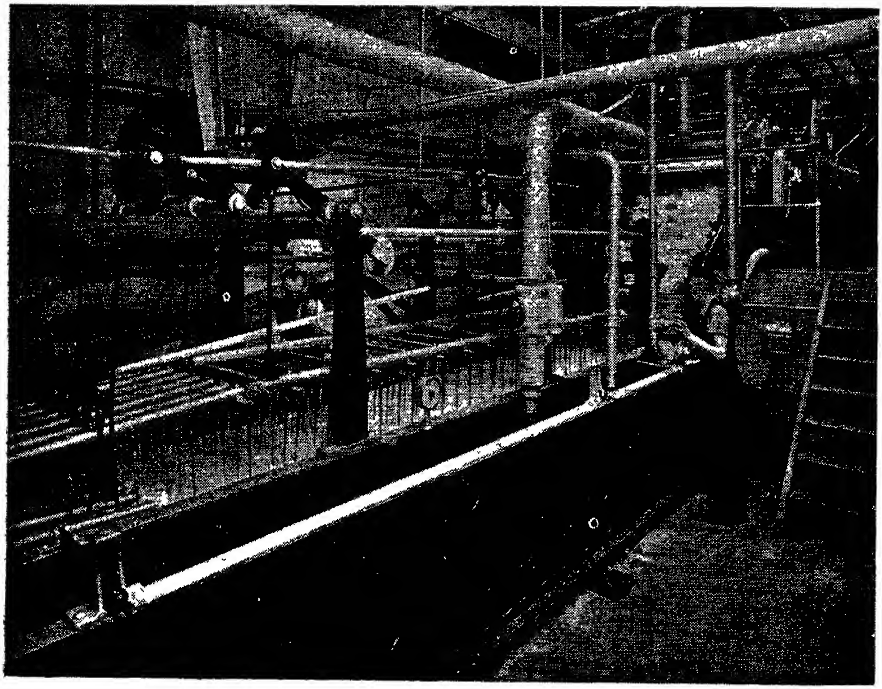
The first machines used in the woollen system, such as the "willow" (or "willey") and the "fearnought," gradually disentangle

fibres and evenly distribute them through the batch. To ensure a good result the operatives must feed the machines with constant amounts of wool at regular intervals and guard against undue damage. These are the "opening processes."

The opened wool is then scoured and fed into the "card" or carding machine which consists of a series of revolving cylinders covered with numerous fine wire teeth or pins (Fig 2). Some cylinders accumulate a web of fibres and in turn are stripped by succeeding cylinders set close to them. During this process the fibres are straightened, separated from their bundle formation and re-mixed but there is no attempt to make them parallel in the web. From the last cylinder the film or web is gathered into loose ropes or "slivers," each of which gains its first resemblance to yarn, although, at this stage, it is weak because it has not been twisted (Fig. 2).

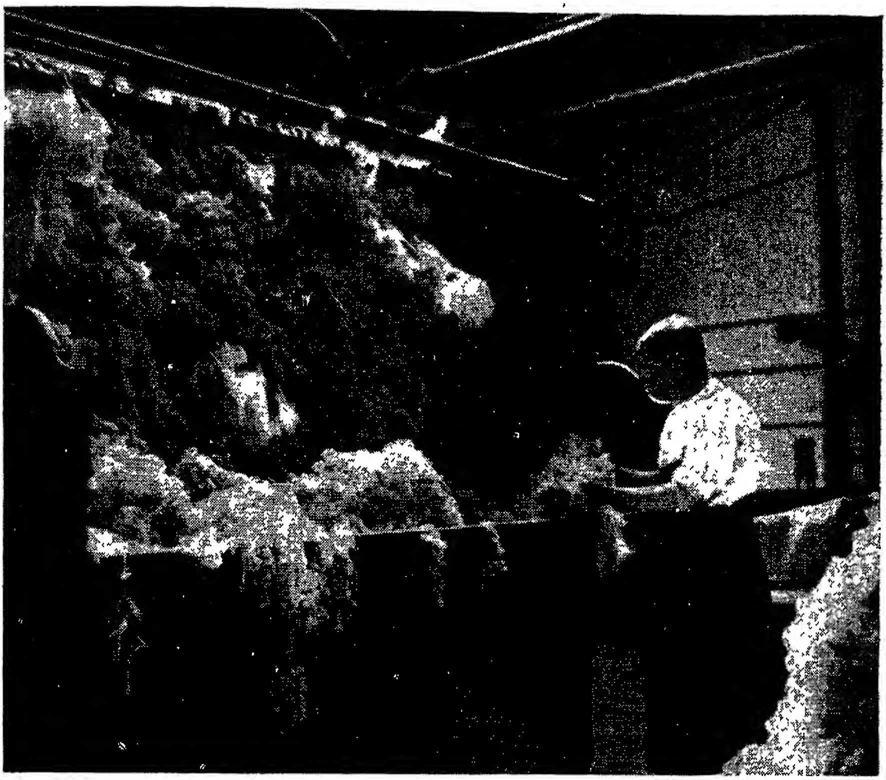
Principles of mule spinning

The untwisted, partially formed yarn is finally shaped by the "mule" spinning frame, which passes the small lengths of web taken from the carding machine through certain rollers to revo ving spindles mounted on a carriage. As this carriage is moved away from the rollers, the strands are thinned and stretched, thereby increasing their length and evenness (Fig. 5). This process, owing to the twist provided by the spindle, favours the thinner sections at the expense of the thicker, so that the latter are easily



SCOURING THE RAW WOOL

After sorting the wool requires scouring to remove all grease, sand, dirt, etc. This is accomplished as shown in the above photograph by passing it through a series of "bowls," each containing a solution of fixed strength. The wool is propelled through the "bowls" by rows of forks.



FEEDING WOOL INTO A CARDING MACHINE

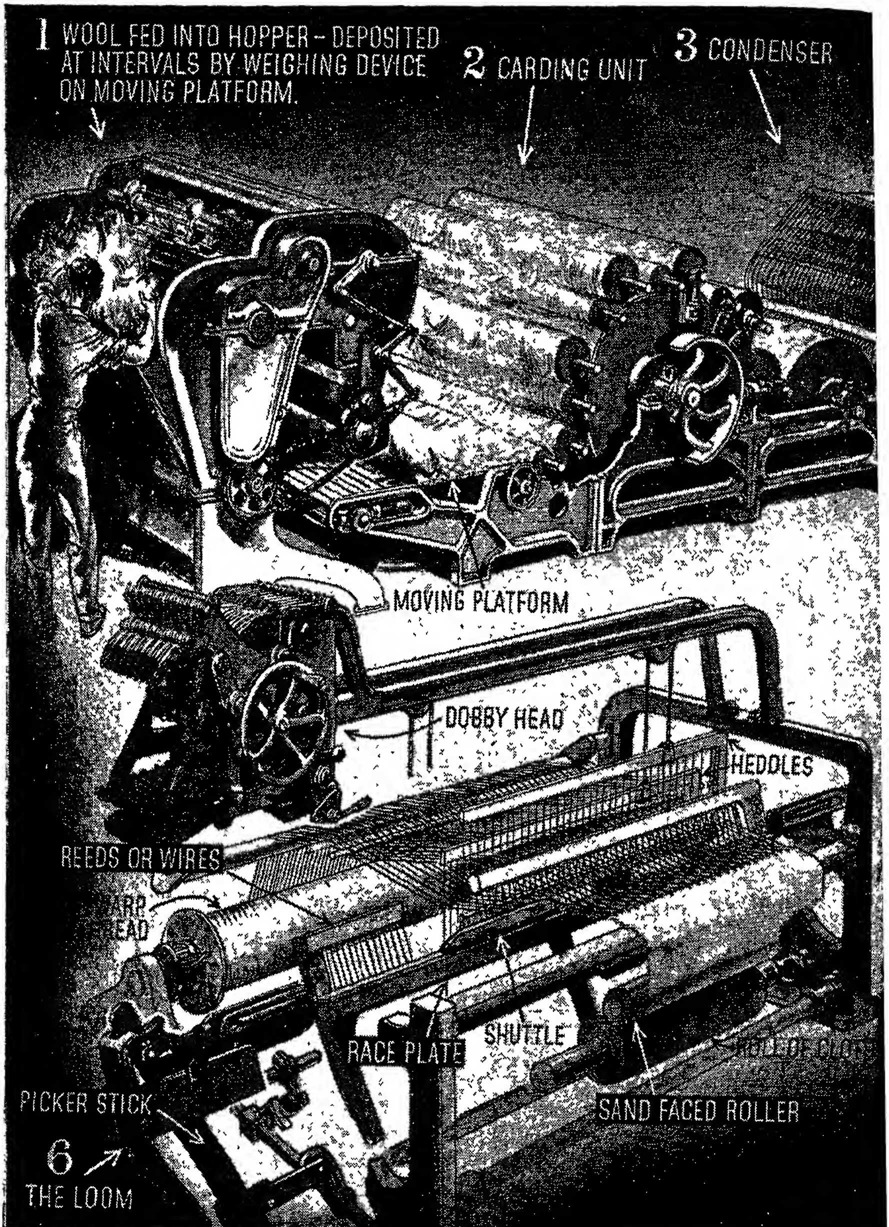
On arrival at the mill the wool is "opened" by machines which gradually untangle the fibres and evenly distribute them through the batch before it is fed into the carding machine, in which the fibres are straightened, separated and gathered into a loose rope or sliver.

drawn out by the stretching action of the mule frame. Each time the carriage returns to the rollers the length of yarn is wound on to the spindle.

This complex mechanism requires the most skilled attention by the spinner and his attendant "pieceners:" young boys who repair broken threads. The mule faithfully copies the advantageous levelling action of hand spinning, but it has not overcome the disadvantage that spinning must stop while the yarn is being wound on the spindle. This inability to spin and wind at the same time is not now regarded with favour and is partly responsible for the method of spinning by rollers, somewhat similar to the worsted process.

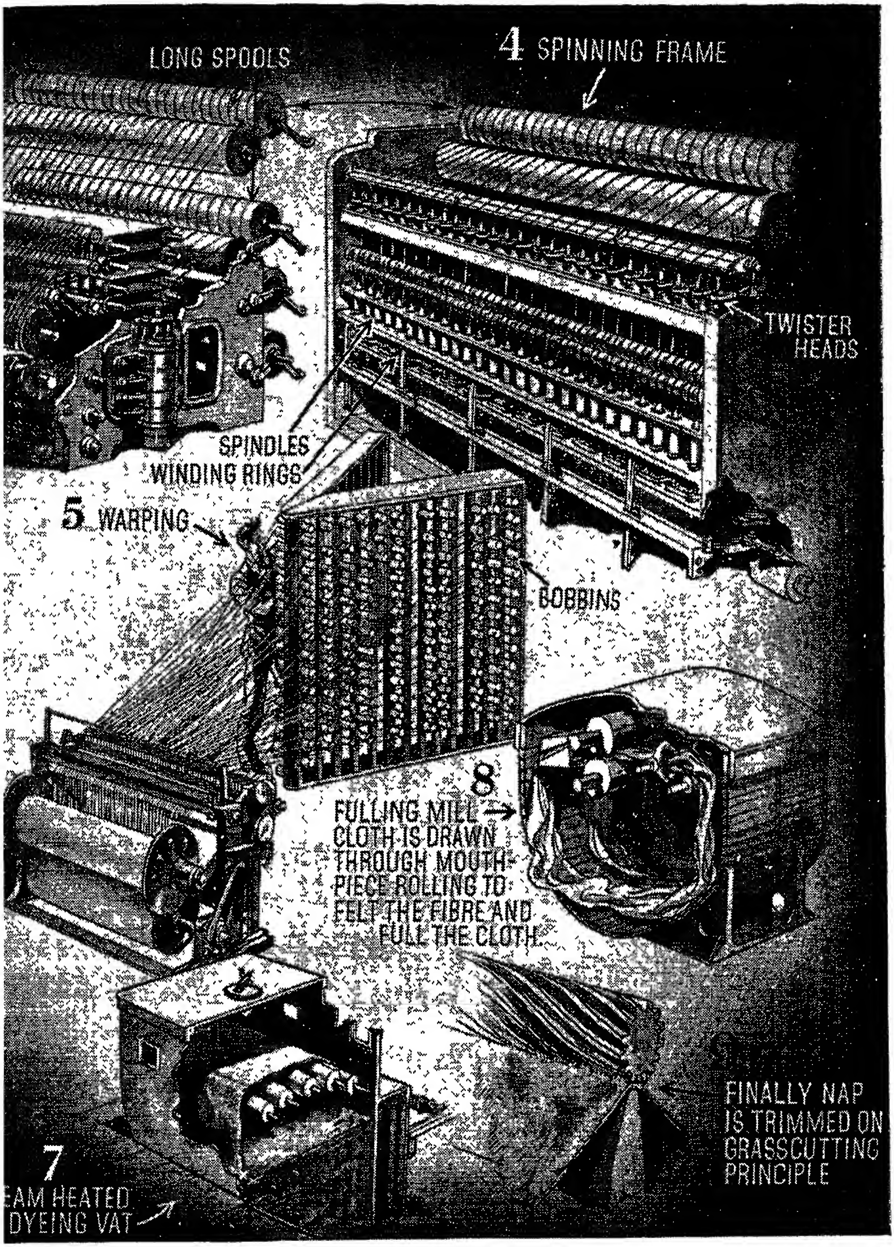
In worsted spinning, fibres are fed in rope-like formation through a slowly revolving pair of rollers which, in turn, passes them to a second pair revolving at high speed. The fibres when gripped by the second pair of rollers are drawn out to form a length of material thinner than that fed into the slower pair, and the unbroken supply of fibres presented to the quickly revolving rollers enables a continuous length of yarn to be delivered.

After leaving this "drafting" process the product is strengthened by a twisting operation. To maintain some semblance of control during drafting, the fibres must all be approximately the same length and parallel to each other, and even then



FROM WOOL TO CLOTH:

FIG. 2. *After the wool has been "opened," it is fed to a hopper (1) which in turn feeds it at regular intervals to the carding machine (2), where the fibres are straightened, separated and re-mixed. From the last cylinder, they are gathered into strands or "slivers," for spinning. Here, as elsewhere, in the drawing, parts of the machinery are removed to reveal the process.*



SOME TYPICAL PROCESSES

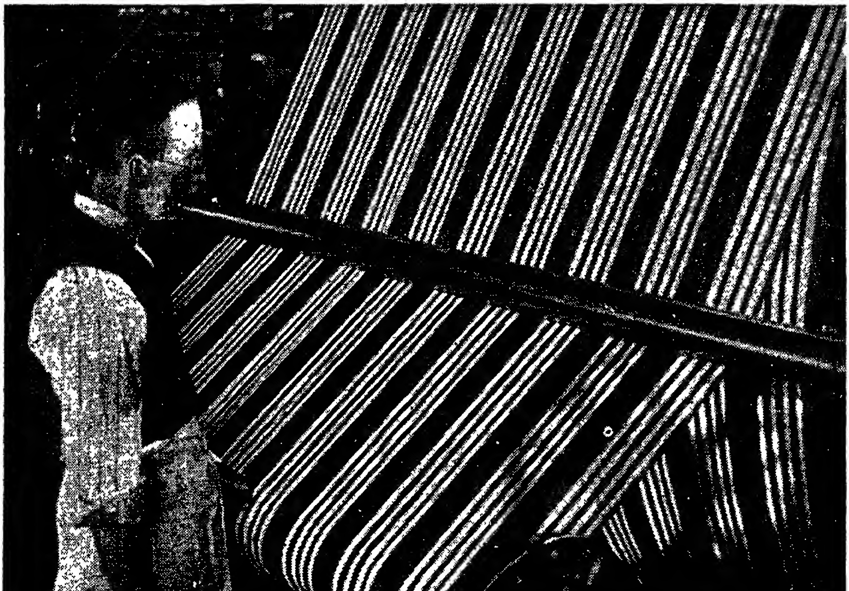
Spinning (4) thins, stretches and twists the strands. To obtain full width of cloth, threads are wound from bobbins on to the weaver's beam (5), which is then placed in the loom (6). Dyeing and fulling are seen in (7) and (8), and (9) shows nap being trimmed by a nicely adjusted cutter. It is by such processes as these that Britain's excellent woollen fabrics come into existence.

it is impossible for the fixed roller system to exercise the same sensitivity in levelling as the twisting operation on the mule. This limitation of the roller drafting method causes worsted processing to be much more complex than woollen and the raw material must be chosen with far greater discrimination.

Wool-sorting for worsted

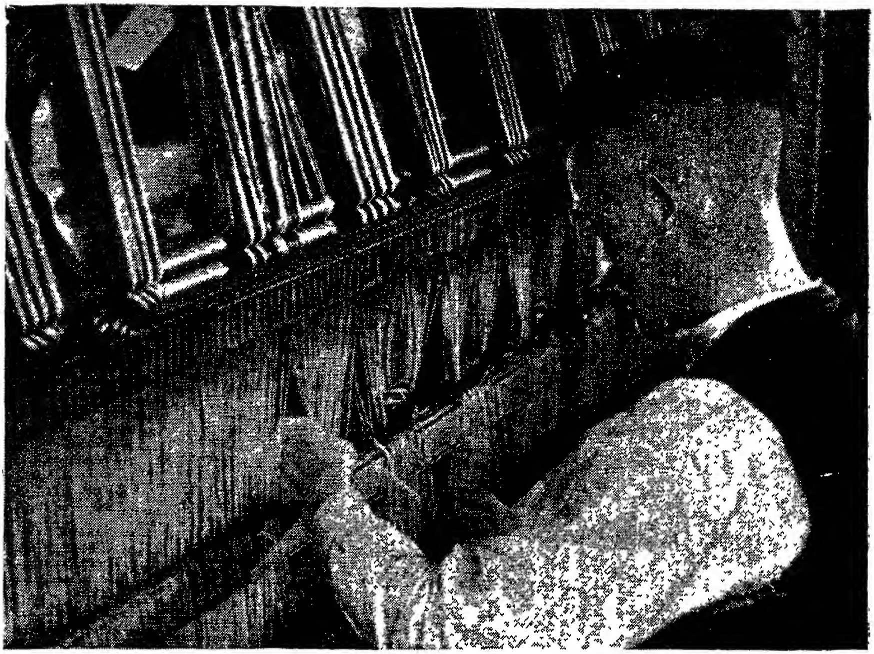
Wool fibres differ according to the breed of sheep and similar fleeces are grouped or "classed" in the country of origin. As previously mentioned, the fleeces contain varying amounts of wool, fat and dirt, and the prospective buyer must estimate the correct net weight of wool per bale from what is, to the layman, a cursory examination of an indiscriminately picked handful of fibres. Unfortunately, there is usually a great variation in the length and fineness of fibres in different parts of one fleece, and for successful processing it is necessary to get together from numerous fleeces the parts that are similar. This selecting is known as "wool-sorting," and the sorter is expert in dividing up a fleece by hand into the different lengths and qualities of wool.

After sorting, the wool is raked through a series of tanks or "bowls" containing soapy solutions which remove the grease and dirt. Hot air in a drying machine takes away the excess of moisture and thus the wool is made ready for the worsted carding process, which is carried out on a machine similar in many respects to the woollen carding machine already described. In this case, the fibres are kept as parallel as possible.



ROLLING OFF THE WARP

Here is seen an operative supervising the rolling off of the warp, or longitudinal threads, on to the weaver's beam. The threads are drawn from the bobbins and wrapped about the beam in even coils. A number of beams may be required to provide sufficient warp for weaving operations.



GETTING READY FOR WEAVING

FIG. 3. *With a dexterity born of long practice, this skilled mill operative draws the end of each thread of warp through a separate eyelet before weaving can commence. During the weaving process the weft, or cross-thread, is automatically interlaced between the strands of warp to form the cloth.*

Stress has been laid upon the necessity of regular fibre length in the production of worsted yarn, and even the wool-sorting process cannot be regarded as a sufficient guarantee of the required degree of regularity. The next process, known as "combing," does secure a satisfactory selection of long and short fibres and is the key to the manufacture of worsted yarn.

There are many methods of combing, all relying on the ability of the longer strands in a fringe of fibres to bridge a measured gap and present themselves to a pair of revolving rollers so that they can be drawn from the bulk. The short fibres, which fail to bridge the gap, are the rejects known as "noils." Although too short for worsted manufacture, these are ideal for forming the leaven in the blends which constitute the material fed to the carding machines in the woollen system. Carding and combing operations are so clearly linked that one manager supervises both, with female labour to replenish the combs and overlookers to make necessary mechanical adjustments.

In the succeeding operations, termed "drawing" and "spinning," the combed mass of long fibres called the "top" is gradually drawn out to a thin yarn by the roller drafting method already mentioned. The slivers are repeatedly combined and thinned in the machines so that irregularities tend to be distributed over long lengths of the final yarn. Groups of "drawing boxes" and spinning frames are attended by women workers who feed the machines and pass the full bobbins to the next group in the line of production. An equitable distribution of the various types of work is ensured by an overseer,

who also makes the mechanical adjustments required by the particular quality of the wool concerned.

From the making of yarn we may now turn to the creation of cloth in the loom. A woven fabric consists of a series of parallel strands of yarn known as the "warp," interlaced at right angles by a second series termed the "woof" or "weft." This interlacing takes place in the loom which has three principal motions. The "shedding" action lifts certain threads of warp above their neighbours so that when viewed from the side of the loom, the threads resemble a V lying on its right side. By the "picking" action, the shuttle carries weft across between the two sets of threads thus arranged in shedding; and in "beating-up" the most recently inserted strands of weft are forced against those previously interlaced.

Preparing the warp

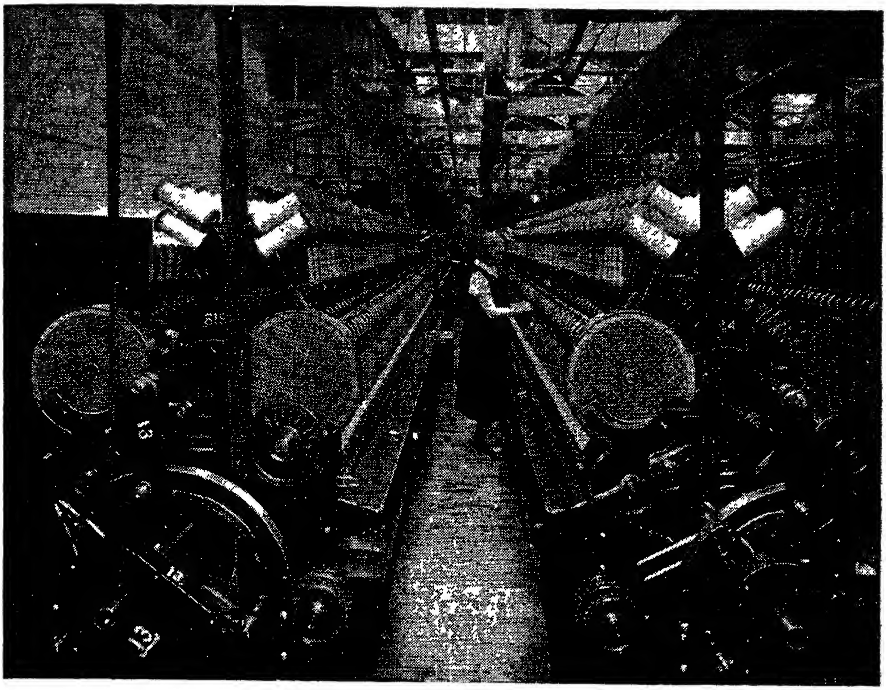
The warp threads required to obtain the full width of cloth are drawn from the weaver's "beam," which is like a huge bobbin and holds sufficient material for long lengths of cloth. The preparation of the warp on this beam demands the close attention of skilled women operatives who fill tall frames with numerous bobbins of yarn, from which the threads are wound along the whole length of the weaver's beam. The beam is further prepared for the loom by drawing the end of each thread through a separate eyelet carried along with hundreds of others on long, slender shafts used for the operation of shedding (Fig. 3).

This tedious work, usually involving the individual handling of thousands of threads, is commonly done by a skilled man assisted by a young boy or girl.

The warp beam is placed in the loom by the weaving overlooker, who is responsible for the correct running of the loom and also acts as adviser on weaving problems to the weavers on the looms in his group. Each loom is attended by a weaver whose duty is to replenish spent shuttles with new supplies of weft, repair broken threads and constantly inspect the cloth being woven, so that the overlooker's attention may be called to flaws due to faulty adjustment of the loom. Lightweight fabrics may be woven on comparatively simple looms which produce at a quick rate; and these can be operated without undue strain by women weavers. Indeed, a weaver may attend three or more looms, if these are automatic. Heavy fabrics must be woven in sturdily built machines worked by men.

The design on the cloth is obtained by altering the order of the interlacings of warp and weft in different places, and varying their reflection of light. From the designer's point of view, looms may be simple or complex according to the number of threads controlled in one unit of the pattern. "Tappet" looms are used for simple fabrics; "dobby" looms for fancy weaves in which precision is especially needed; and "jacquard" looms for cases in which the pattern may extend several inches across the cloth. Broadly speaking, weavers trained to one of the three types become so specialized that they rarely transfer to the others. Even within a single group there are special mechanical features which tend to keep the operative to one kind of work.

A wearisome feature of weaving is the continual replenishment of the shuttles, requiring the stopping of the loom with a consequent loss of production. Certain types of loom can automatically replenish their spent shuttles, thus—providing the fabric structure is simple—permitting an increase in the number of looms one weaver can operate. This has developed a new weaving technique which devotes more attention to the repair of faulty weaving and less to scrutiny during weaving, because the loom automatically stops when threads break and an indicator



SPINNING WORSTED YARN

FIG. 4. *For the production of hard-wearing worsted cloths, cap spinning is the method used. Fibres are fed through a slowly revolving pair of rollers and gripped by a second pair which draw them out to form a length of material thinner than that fed into the first. The fibres are strengthened by twisting. Above is seen an impressive vista of machines used for cap spinning.*

attracts the weaver's attention. Such intricate mechanisms call for more specialized skill in the overlooker, who must have considerable engineering ability besides proficiency in the processing of cloth. To run economically, automatic looms should produce long lengths of fabric from one warp beam, thereby tending to mass production in design.

As the success of a large part of the wool textile industry depends upon the variety of the designs produced, the importance of the cloth designer must be emphasized. Besides originating new styles, his duties in an ordinary firm may include analysis of fabrics, emulation or imitation of the design of existing cloths, and checking of fabrics in the loom.

After weaving, each piece of cloth is carefully scrutinized, and faults invisible to the untrained eye are corrected by "burlers" and "menders." The burler draws out thick threads, opens out any knots, and pushes loose ends from the face to the back of the cloth. Menders insert yarn where threads are missing.

The three most usual ways of dyeing wool are as loose wool, in tops, and in the form of cloth. In the first and second methods opportunity is taken to mix fibres of various colours and spin them into "mixture" yarns for use in the more exclusive types of fabric. Such cloths require simple treatment in finishing and are first washed in large "scouring bowls" whose rollers repeatedly squeeze and immerse long lengths of fabric in soap solution. Cloth about to be "piece-dyed"

MULE SPINNING

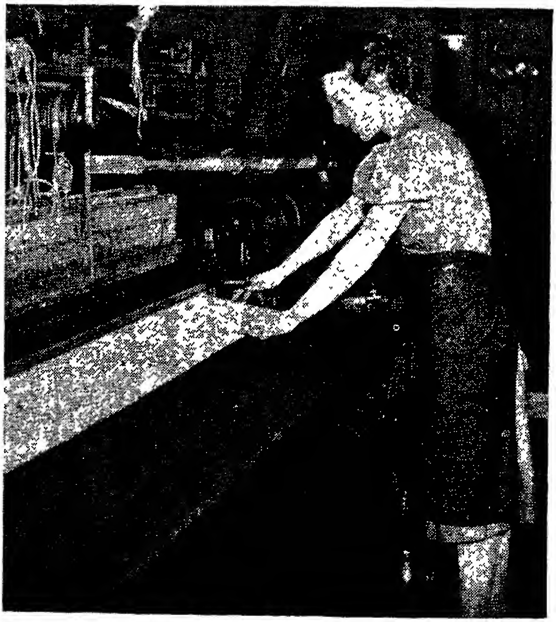
FIG. 5. *Above are mule spinning operations, in which the partly formed yarn is thinned, stretched and wound upon the spindle.*

properties in combinations of colour, which may vary in comparatively short lengths of cloth. This technical skill on the dyer's part allows a large volume of material to be spun and woven, and postpones the colouring of the fabric until as late as possible in the series of manufacturing processes: an important provision in view of rapid changes of fashion.

Compact and full-handling fabrics are usually secured by the milling or "fulling" process, and the milling machine obtains the effect by drawing a length of moist cloth from a confined space against the

WEAVING BLANKETS

This close-up photograph gives a detailed view of blanket weaving, with the woman operative adjusting her machine. See below.



must also be cleaned in this way, and the scourer must ensure the complete removal of oil from the yarn to avoid complications in dyeing. It is possible for fibres with different dyeing properties to be woven in one fabric to reduce costs or imitate "mixture" effects by cloth dyeing. If the former, the dyer may colour the cloth to conceal differences in fibre types. Alternatively, he may tastefully reveal the fibres' contrasting dyeing

resistance of a weighted lid. The miller must prevent undue shrinkage by repeatedly stopping the process and measuring the contraction of the cloth. If, after milling, the wool fibres do not project sufficiently from the body of the cloth, it may be necessary to lift and lay them systematically on the surface of the fabric. This operation, termed "raising," draws the cloth into contact with rapidly revolving vegetable "teazles" or wire brushes, circular in form, which pluck and raise the fibres.

Obviously, prolonged raising would weaken the fabric and this must be avoided by the operative's careful supervision. The milling and raising processes leave fibres projecting irregularly from the surface of the cloth and these can be cropped to one length by a cutting machine similar in principle to a lawn-mower. The cutting blades must be accurately set at the required distance from the cloth by the finisher, who must also be on the alert to prevent damage to the cloth by the knife of the machine. The remaining processes of cloth finishing include pressing and brushing and steaming which slightly raises the fibres, thus obviating any excessive gloss due to pressing. When fully "finished," the fabric is wrapped in measured folds, made into bundles and packed in canvas for dispatch to the merchant, and so to the world.

An industry cannot thrive merely by possessing raw materials, mills, machines, and workers. Consumers must be found for the products, and the study of markets is a vitally important part of wool textile activity. Here we encounter one of the critical problems of the industry's welfare. Whereas a fashion used to run for a season of many months' duration, normal modern life calls for frequent changes. This rules out bulk production of any particular type of cloth, and small firms, it is contended, can ring the changes with

PREPARING FOR THE LOOM

Shown above is a weaver engaged upon filling a frame with weft bobbins ready for insertion in the shuttle—one of the many tasks in which women figure in this industry.

greater success than large organizations, to which frequent adjustments are uneconomic. It is sometimes debated whether the caprice of the consumer should be indulged in such detail but, as yet, no plan (other than war-time control) has been devised for a co-operative limitation of styles by producers.

Staple fibre cut into lengths suitable for blending with various types of wool is being increasingly used. When mixed with wool, delustred staple fibre, specially treated to be crease-resisting and to take a wool dye, cannot be distinguished from pure wool by the eye and touch of the layman.

PIECING AN END

No detail however small is overlooked in a cotton mill. The above photograph shows a woman worker engaged in piecing up a broken thread. Such precise and delicate work is especially suitable for feminine fingers, as it is essential that the knot should be very neat and the ends should be broken off very short or serious flaws in the completed material may ensue.

THE STORY OF COTTON MILLS AND THEIR METHODS

By E. Ostick

From plantation to mill—raw cotton to finished fabric. Loosening and cleaning. The all-important sliver: its progress to "jack roving." What the carder does. Drawing and slubbing frames. Spinning machines; and how weavers run their looms. How your cloth is dyed, bleached and printed, and how it is finished.

We take so much for granted. When most of us think of cotton, it is as a finished material, an accomplished fact, without heeding the multiple processes involved in its manufacture. From plantations where coloured workers toil in the sunshine, to the weighing and separating plants; from shipment to the mill thronged with busy operatives, and so to the product familiar to us—these stages escape us. Thousands upon thousands of useful lives are wound for us on to a cotton reel.

The United Kingdom imports its cotton from Egypt, India, Brazil and many other parts of the world, but the largest proportion comes from the U.S.A., where it is principally grown in the south and south-eastern states. In the State of Mississippi, for example, there are hundreds of cotton plantations on which thousands of negroes work during the harvest. When the cotton bolls ripen these split open, and expose their seeds enveloped in white fibres ready for gathering. When the harvest begins, negroes and negresses and their children troop into the fields to pick the ripe cotton by hand. A mechanical picker is being gradually introduced into the cotton plantations, but hand-picked cotton is cleaner.

When the cotton has been picked and weighed, it is sent to be "ginned;" that is, the fibres are separated from the seeds by machinery. The raw cotton is then tightly compressed into bales and despatched by rail and sea to England. Finally, the bales arrive at a Lancashire spinning mill; and there we meet them.

On arrival at the mill the bales of cotton are weighed. Inspectors open some of them to ascertain whether the contents agree with the sample on the strength of which they were bought.

Primary processes

Before being spun into yarn, cotton must be loosened, cleaned, and converted into a convenient form for handling. These processes are performed by machines known as "bale-breakers," "openers," "scutchers," and "lap machines," from which the cotton emerges in the form of a continuous flat band or "lap," with the heavy impurities removed. Cotton yarns are usually spun from mixtures of cotton and blending needs skill. Mostly, the mixing is done by machine, but the advantage of hand-mixing is that the cotton is better blended and gives more uniformity in the quality of the yarn. In a spinning mill a considerable amount of fine fluff collects on the machines, and if this were allowed to accumulate, the resultant yarn would be lowered in quality because the machines would be incapable of doing their work efficiently. At intervals, all machines

undergo a thorough cleaning (Fig. 1).

After the cotton has been loosened and some of the dirt and grit removed in the opener, it is passed to the scutching machine which further cleans the cotton and delivers a lap of uniform thickness and weight. The lap of cotton next passes through the "card," a machine that removes the finer impurities which were not rejected by the bale-breaker, opener, and scutcher. The carding process also extracts short or broken fibres, loosens the matted mass of fibre almost to a gossamer web, and then rolls it into a thick loose rope, called a sliver (Fig. 3).

Drawing and slubbing

The whole process of cotton spinning resolves itself into a series of drawings, doublings, and twistings. From the carding machine the cotton issues in the form of a ribbon-like sliver. Now it is taken to what is called a "drawing frame," where a number of these slivers will be united into one. The drawing frame consists of three parts or heads, each acting independently of the others. Six cans containing slivers from the carding machine are taken to the first of these heads for the formation of a new sliver. The slivers are grasped by rollers, running at varying and nicely-adjusted speeds, which deal with them with a finger-and-thumb movement. This unites the slivers in one, at the same time drawing this out to the required length, and coiling it once more into a can. Six such slivers are then taken to the next head and the process is repeated. Often a third combination of six is made so that the resultant sliver may contain 216 of the original slivers as they issue from the carding machine. To such automatic perfection has this machine been brought that it instantly stops if one of these light slivers should break.

The drawing sliver then passes through a number of "slubbing frames" which reduce the sliver in diameter and impart a slight twist so that it is strong enough to be wound on a bobbin. In preparing the better and finer qualities of cotton yarn, these slubbing processes require specialized machinery, shown in Fig. 5.

Types of spinning frames

The last sliver from the slubbing frames is called a "roving," or "jack roving" when the sliver is exceedingly fine. The roving bobbins are now taken to the spinning frames where the fine roving is drawn out, twisted into a yarn, and wound up in the form of a cop. There are two main types of cotton spinning machines (Figs. 4 and 6), namely, the "self-acting mule," evolved from Crompton's invention (*ca.* 1779), and the "ring frame," developed from Arkwright's water frame invented about 1769. In Great Britain in 1928, there were sixty million spindles making cotton yarn; in 1936, there were forty-five million, and in 1940, thirty-eight million. Ring-frame spinning produces a greater weight of yarn per hour than the mule. Women usually operate ring spindles; mule frames are operated by men. In mule spinning exact adjustment of the machine, constant vigilance, experience, skill and rapid action are necessary if the best results are to be obtained. The operatives employed on the mule are men and boys, called "minders" and "piecers." Each minder takes charge of a pair of mules working opposite each other. He has under him a "big piecer" and "little piecer," whose duties are to piece (that is, to mend) the ends of broken threads, keep the mules clear of waste and gather the cops from the spindles.

Temperature of the mill

In the spinning mill the temperature and humidity should be correctly adjusted if the best yarn is to be obtained from the cotton. All new mills are fitted with humidifying and ventilating appliances.

CLEANING THE MACHINES

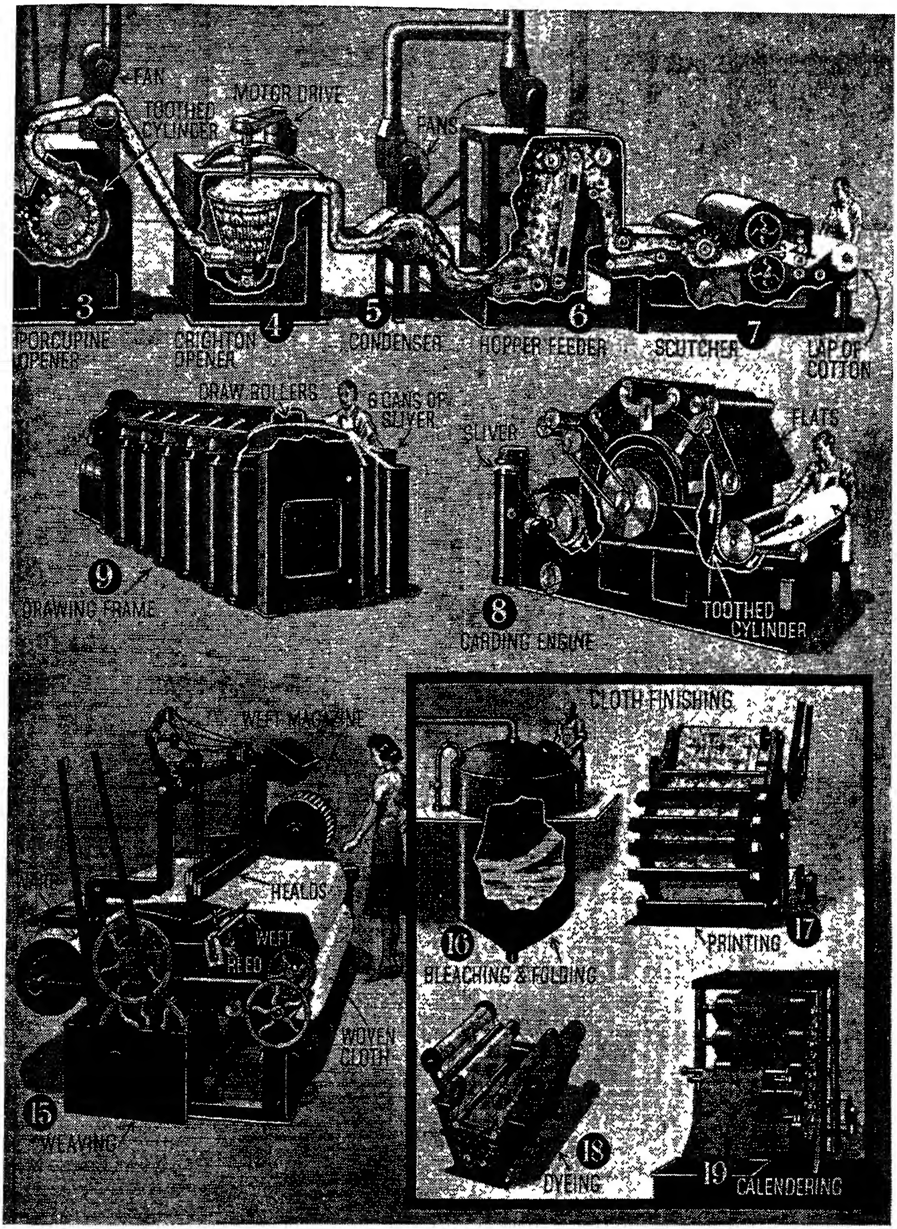
FIG. 1. *Clean machines are always the workers' pride—especially in a cotton mill where the nature of the material renders it more than ever necessary. Above, a girl is busy clearing away cotton waste.*

Not only do these appliances humidify the air; they free it from soot, and thus keep the cops of cotton clean. Working conditions for the operatives are also improved by such methods.

Throughout the cleaning, drawing, doubling, and twisting processes, the raw material consists of short hairs or fibres. To combine these fibres into a long, strong, and uniform thread represents a

FROM COTTON BOLL TO FINISHED CLOTH:

FIG. 2. *From plantation to mill, from bale-breaking to calendering, most of the significant processes of British cotton goods manufacture are here indicated in their order of progression. How the bale of cotton is fed to the hopper bale breaker, and eventually appears as a lap at (7), is shown in a drawing made specially to indicate the internal mechanism of the various devices.*



HOW COTTON GOODS ARE MANUFACTURED

It is not until the lap of cotton emerges that it is again touched by human hands. Thereafter the cotton passes through numerous processes until it is woven into cloth, which then undergoes the "finishing," as seen in the lower right-hand corner, undertaken by the "commission trades." A closer, more explanatory view of the process of printing cotton (17) will be found on p. 171.

high combination of good judgment, manipulative skill, organization, and mechanical knowledge.

As it comes from the spinning mills, the yarn is of two types—twist and weft. Twist forms the thread which runs from end to end of the cloth, and is called "warp." The weft threads, or "picks" of weft, pass from edge to edge of the cloth, and are sometimes called "woof" or "filling." Twist yarn, having to bear a greater strain in the course of manufacturing, is usually stronger than the weft.

After spinning, the first process is that of winding, the object of which is to place a certain length of yarn on the spool or bobbin. The operation of winding is simple, and is readily learned by girls or women. Their work consists in replenishing the yarn and piecing up broken threads. It is essential that in piecing the thread the knot should be neatly made and the ends broken off very short. An ingenious apparatus does this automatically; strapped to the hand of the winder, it makes the knot and snips the ends.

Warping and sizing

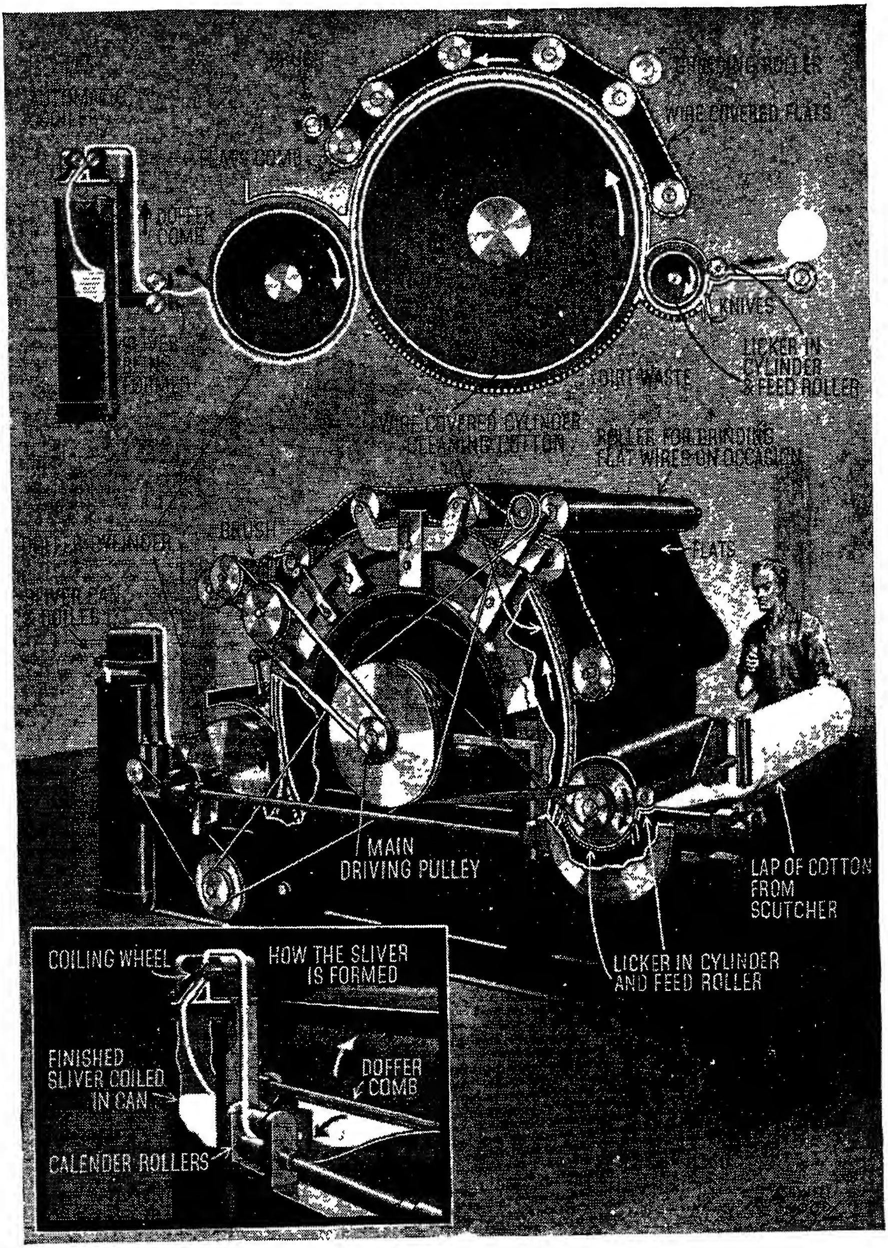
The second process in preparing the warp for the loom is that of warping, in which yarns are transferred from warper's bobbins to a large flanged beam in the form of a wide sheet. For women, the work of warping is pleasant employment. Following the warping process is that of sizing, which consists in applying a paste to the yarn to strengthen it and enable it to withstand the friction and tension in the loom during the weaving operation. Some folded yarns will weave quite well without size, but single yarns for the warp must be sized. The work of sizing is done by men well organized as a trade; and so another process is completed.

After sizing, the yarn is dried and run on to beams; these beams holding sized warp are now taken into the looming room, where the threads of the beam are attached to the "healds" and "reed." In a loom, a heald is the guide of a warp thread; the reed, the device that separates the warp threads. Since it is necessary that the warp threads may be lowered or raised in various combinations to allow interlacing with the weft, each warp thread must be passed through an eye in the centre of a harness wire. The passing of the ends of warp through their proper harness wire is an operation requiring some skill. The actual drawing-in is usually performed by an experienced worker of either sex, who sits in front of the harness and is assisted by a "reacher-in"—a boy or girl who sits behind the harness on the same side as that on which the sheet of warp threads droops.

Drawing-in simplified

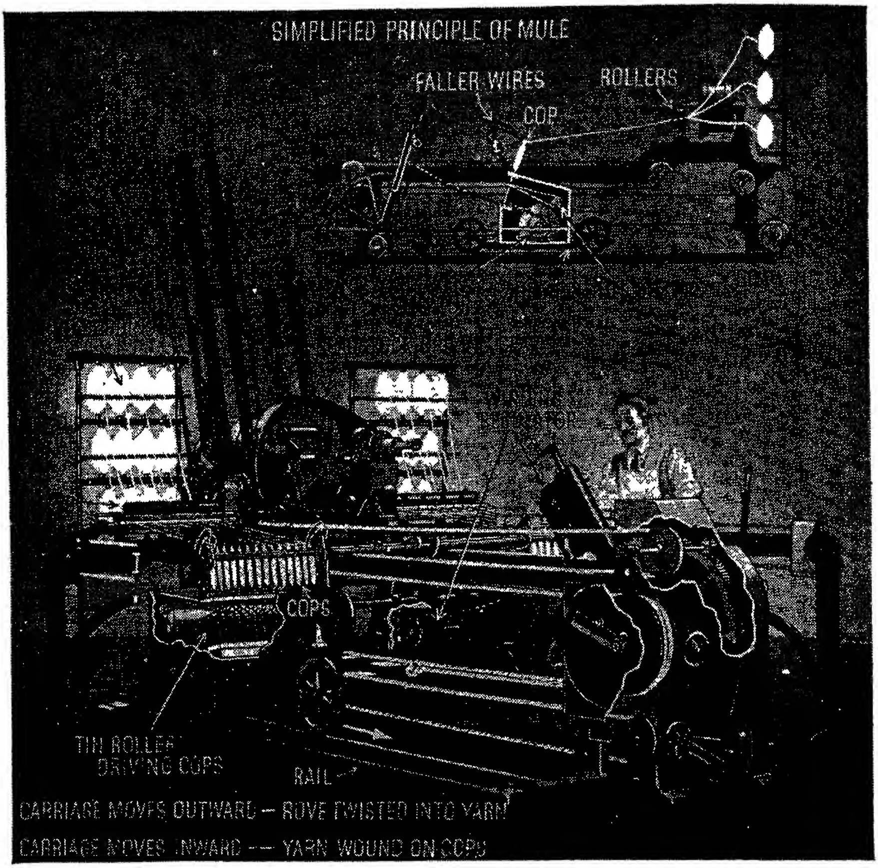
Drawing-in does not demand any undue mental or strenuous physical effort or special technical ability. Nevertheless it is a tedious and monotonous occupation requiring dexterity and diligence. Of late years, however, very considerable improvements have been made in these frames to render the operation of drawing-in less fatiguing for the worker. A mechanical reacher for drawing-in frames has been installed in many mills and this device dispenses with the youth usually employed to select the warp threads for the drawing-in operator.

When the drawing-in is completed, the beam of warp with the healds and reed is taken to the loom, the various parts being fixed on the framework. The warp passes over the back rest to the healds and through the dents of the reed; in the process of weaving the healds jerk up and down, forming and re-forming the "shed" through which the shuttle passes. The weft is skewered in the shuttle, driven by the picking stick from side to side and interwoven with the warp. After each pick the reed drives home the new thread against the preceding pick.



BIRTH OF THE SLIVER

FIG. 3. *From the scutcher (see Fig. 2, No. 7), the lap of cotton goes to the carding engine where the sliver is formed. Above, the whole process is simply explained. Basis of all cotton materials, the sliver then goes to the drawing frame—next stage on the way towards the finished product. In the middle portion of the drawing, the sequence of the process must be "read" from right to left.*

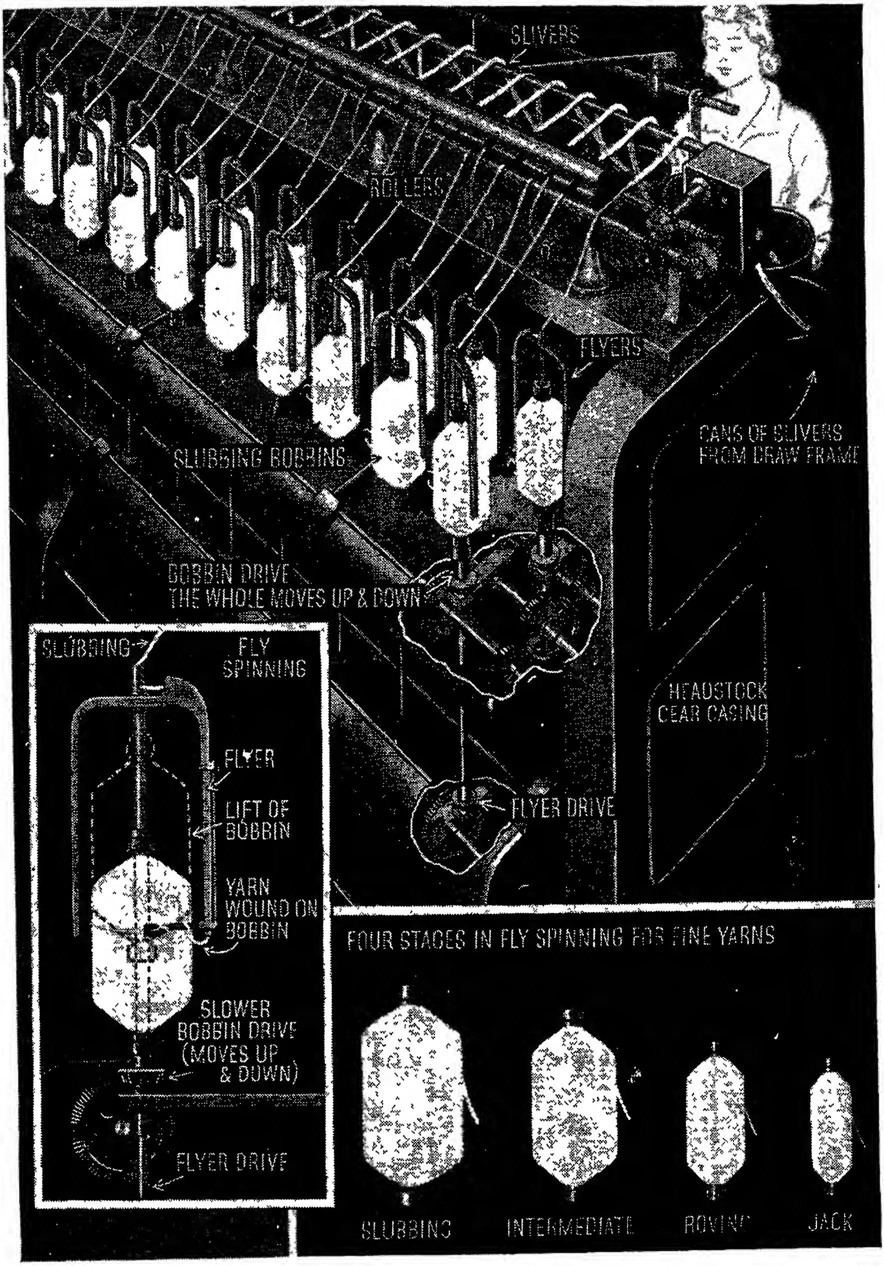


SELF-ACTING MULE

FIG. 4. *One of the two main types of spinning machine, the "self-acting mule" is demonstrated in this illustration. Mule frames are operated by men and boys called "minders" and "piecers," each minder taking charge of a pair of mules, with a big and little piecer to help him in his work.*

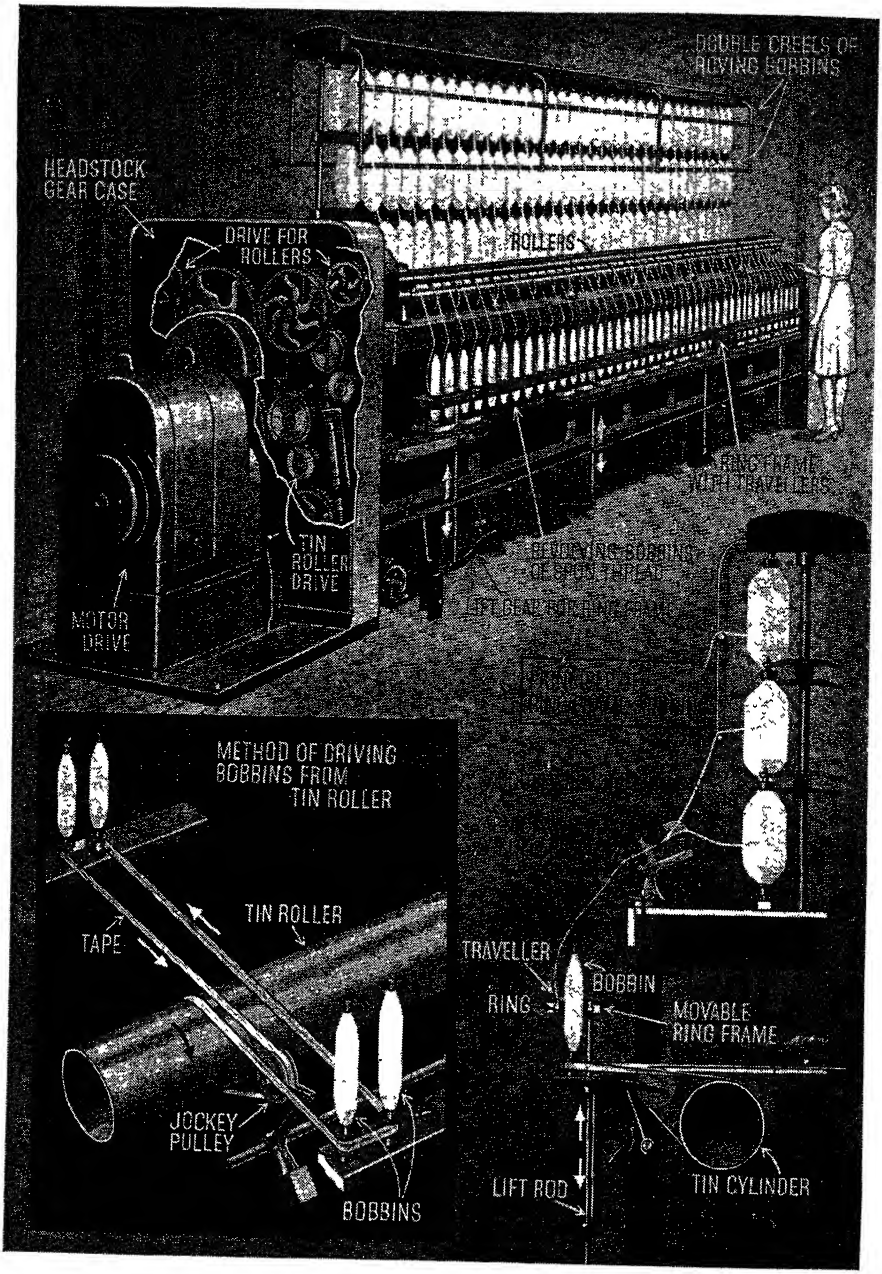
A loom requires a considerable amount of repairs and renewals. These are delegated to an overlooker, usually called a "tackler," who has charge of about a hundred looms. If fancy goods, that is figured cloths, are being woven, then fewer looms are under the tackler's control; if plain narrow cloths are being woven, the tackler may be in charge of 150 looms. The tackler's work is to keep the looms supplied with warps, gait them up, repair or tackle the looms, and perform many other essential duties.

There are various forms of looms, and the appliances for making different patterns and qualities of cloth are innumerable. Briefly stated, weaving consists of three operations: (1) "shedding," that is dividing the warp by lifting up certain threads and leaving others down to form the desired interlacing of the warp and weft; (2) "picking," or throwing the shuttle between these two sets of threads leaving a pick of weft in the "shed;" (3) "beating-up," bringing the pick of weft up to the one which preceded it. The



SLUBBING ON THE FLY FRAME

FIG. 5. *Slubbing, which reduces the drawing sliver in diameter and strengthens it by twisting, is performed on fly frames as seen above. Thus the sliver is prepared for winding on bobbins, being now known as a "roving" or "jack roving." The bobbins then go away to the spinning frames.*



FINAL PROCESS IN SPINNING—THE RING FRAME

FIG. 6. *Unlike mule frames (Fig. 4), ring frames are usually operated by women. From the ring frame the bobbins go for spool winding and other treatment on their way to the weaving loom as seen in Fig. 2. How the ring frame functions is explained in the specially prepared picture seen above.*

shedding is effected by three distinct sets of appliances termed "tappets," "dobbies," and "jacquards," which are limited to the formation of simple, medium and complicated designs. These are again subdivided into numerous types of each sort; each with its own peculiar advantage to some special make of cloth.

Weaving plain cloth

In the weaving of plain cloth, the average weaver runs four looms, but in many mills provision is made for three or even two-loom weavers, while they are qualifying themselves for the higher number. In some north-east Lancashire towns, five- and six-loom weavers are not infrequent on narrow strong goods. The weaver's duties consist of piecing up the broken ends of warp and drawing them through the heald and reed, filling the shuttles with weft and placing them in the loom as those in working become empty, oiling, doffing "cuts," and performing simple repairs. The essential difference between the common Lancashire power loom and the so-called automatic loom is that in the latter, when the weft breaks or is exhausted, the shuttle is automatically recharged with weft and threaded without being removed. All that the weaver has to do in regard to the weft is to keep the magazine charged, and the loom will then run for some two hours, unless it be stopped by the breaking of a warp thread. Though invented by an Englishman, the extensively-used automatic loom has not yet been adopted on a large scale in Britain.

From the weaving shed the weaver takes her cuts or pieces of cloth to the warehouse where they are put on the folding machine, which hooks the cloth in folds of one yard.

The cuts of cloth (marked with the weaver's loom number) are then carried to the cut-lookers who rapidly examine the cloth to discover any imperfections. The cut-looker reports any flaws or faults in the cloth to the weaver, and throws out as "seconds" those pieces which are not up to the required standard. For cloth faults due to the weaver, such as "floats" caused by failure to interweave at some point, the weaver is "bated," or fined, according to the seriousness of the fault. In the warehouse the cloth is made up into bundles ready for despatch.

But to return to the cloth which has been examined by the cut-looker. If the goods are to be shipped in the "grey," the cloth is sent to Manchester when it undergoes a second scrutiny prior to packing. Cotton cloth direct from the loom is known as grey cloth, because it has a grey or yellowish appearance due to impurities. If the goods are to be bleached or receive some further treatment, they are packed, despatched by rail or motor lorry to the bleach works where they will be treated in accordance with the instructions of the merchant or the shipper concerned.

Previous to the actual bleaching operation, the pieces of cloth are singed, that is, the fine projecting fibres are burnt off the surface of the fabric. The singeing operation is performed by rapidly passing the cloth, in open width, over red-hot copper plates or between rows of Bunsen burners. Singeing smoothes the surface of the cloth, thus giving it a more attractive appearance when subsequently dyed or printed. After being singed, the cloth is passed through a trough of water so that any sparks on the cloth may be immediately extinguished. The cloth is now ready for bleaching.

Bleaching and mercerizing

By far the greater quantity of cotton is bleached in the piece, though this can be done at any stage, before and after its manufacture. Cotton is bleached in the loose state for the preparation of absorbent surgical wadding, and also for the

preparation of gun cotton. Yarn is bleached for use in woven goods, for sewing threads, crochet cottons, laces, and embroideries. Cloth-bleaching is carried out with one or more objects in view: firstly, that of supplying a pure white cloth for sale in the domestic markets of the world; secondly, of producing a white cloth in preparation for the process of printing; and thirdly, of preparing the grey cloth so that the dyer can exercise his skill in colouring it in light, medium, or dark shades.

Impurities removed

The natural impurities in cotton, in the raw state and as yarn, consist of fatty acids, wax, colouring matter, etc., amounting in all to about five per cent. of the material. In addition, cotton cloth contains the various sizing materials, such as starch, wax, soap, etc., previously added to facilitate the weaving. Bleaching removes these impurities and leaves the cloth in such a condition that it is capable of evenly absorbing the various colouring matters applied to it.

Cotton yarn and cloth are often mercerized, thus giving the cotton a permanent silky lustre, and increasing its affinity for certain dyes. Cotton may be mercerized before or after the bleaching process, and cloth woven from mercerized yarns possesses a higher lustre than that mercerized in the piece. After mercerizing, sewing and crocheting cotton threads are as lustrous as spun silk.

As there is a considerable demand for coloured goods, the dyeing and printing sections form a very important branch of the cotton industry. The main object in dyeing is to ensure a perfect union between the material and the colouring matter, so that the colour will not be seriously affected by light, washing, or friction. Let us see how this is ensured.

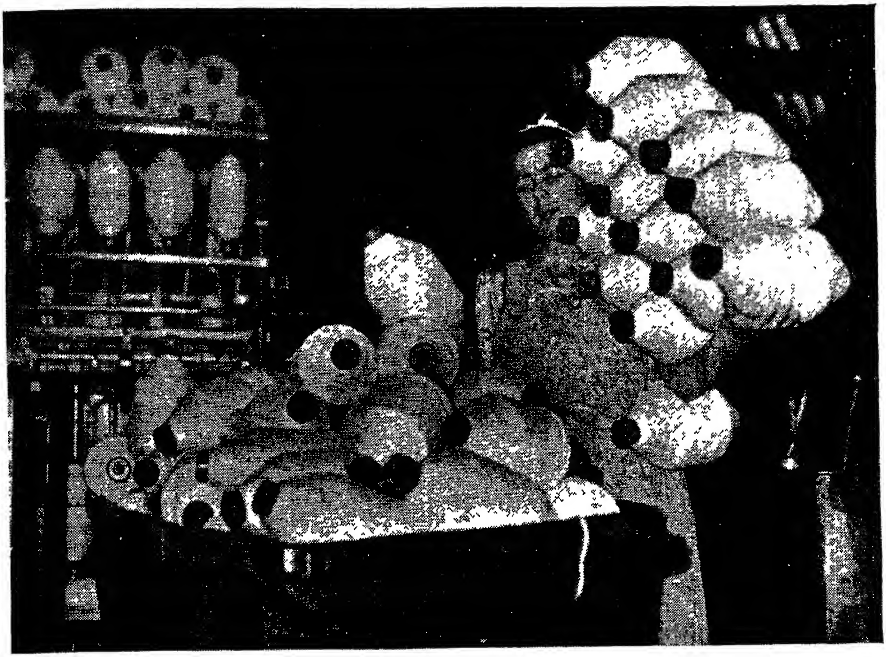
Cotton is dyed at almost every stage of its manufacture. In the dye works are found specially constructed machines for the dyeing of loose cotton, slubbings, rovings, yarns, and cloth. The operation is much more than a mechanical process; success depends very largely upon the dyer's care and skill. Cloth is dyed by immersion in a more or less heated solution, and generally in machines which carry the cotton fabric through the dye solution at open width. In most cases a machine called the "jig" is used. The dye is mixed in a separate vessel and then added to a certain amount of water already in the jig. The fabric is circulated through the dye liquor until the required depth of shade is obtained. It is then washed, squeezed in a mangle, and dried. Cotton yarn dyeing is practised to obtain coloured warp and weft for use in checked and striped patterns. Yarn is usually dyed in the hank form and may be done by hand or machine; where large quantities have to be treated, the latter is the more economical method.

In dyeing cotton, or any other material, the dyer must exercise good judgment. He must take care that the dyestuff he uses is completely dissolved and that the temperature of the solution is right; he must mix the ingredients in the correct proportions to obtain a thorough and even penetration of the dye liquor. In practice, the dyer is expected to treat as much cloth as he can with as little dye as possible.

How cotton is printed

After being bleached, many cotton fabrics are sent to the printing works where the material is impressed or stamped with one or more colours to form a pattern. Cotton prints are very much more plentiful than any others, and the process is generally known as calico printing, although many cottons, other than plain calico, are submitted to such methods of decoration.

By far the cheapest, and therefore the most common, is the method of printing



BOBBINS FROM THE CREEL

From the slubbing frame, a woman worker is removing the full bobbins of cotton slubbings, which are later spun into cotton yarn as shown in Fig. 2, No. 11. The yarn is then wound on spools, warped and sized, and finally woven. Creels are the frames which hold the paying-off bobbins.

cotton cloth by the copper cylinder or roller. The modern printing machine has a series of copper cylinders on which the design to be printed is etched or sunk. The colour paste is carried in a box in which a wooden roller revolves. This in turn carries the colour to the engraved roller, which thus becomes coated with colour. As the patterned roller revolves, the colour, except that in the etched portions, is scraped off by a blade, usually called a "doctor." The etched roller then comes into contact with the cloth and the colour in the engraved lines is transferred to the cloth. If the design requires six colours there will be six rollers at work, and so on up to twelve or fourteen colours at a single run through the printing machines. The output of the machine is enormous, up to 20,000 yards of cloth in one colour and 10,000 yards in ten to twelve colours being printed in one working day (Fig. 7).

Effect of hand printing

Hand block printing, the oldest and simplest of the various methods of printing on fabric, is slow and costly. Cylinder printing is preferable for designs where mechanical accuracy and delicacy of detail are involved, and when production costs have to be reduced to a minimum. But block printing produces designs unsurpassed for their breadth of effect and decorative value. Compared with the mechanical efficiency of a cylinder print, the rich colour obtained from a good block print reveals the beauty of individual workmanship over the sheer repetitiveness of mass production.

When designs of fine outline and delicate detail are required for reproduction by block printing, coppered blocks may be used. These blocks are hard pieces of wood, usually three-ply, and about 2 in. thick; upon these blocks the design is built up in strips of copper or brass.

This type of block is very useful for printing fine outlines, but gives a harder and more mechanical effect than that of the ordinary wood block. There are other methods of cotton printing, but whichever method is used it is obvious that the skill of the printer is of first importance.

Finishing processes

Even when the cotton fabric has been bleached, dyed, or printed, it is not yet ready for sale in the market. Cotton goods which have been subjected to one or more of these operations are put through "finishing" processes, calculated to increase their attractiveness, to add to their utility, or both. Finishing is the final stage before the cloth reaches the consumer, unless it is to be made into garments, in which case it is despatched to the clothing factory.

Cloth development

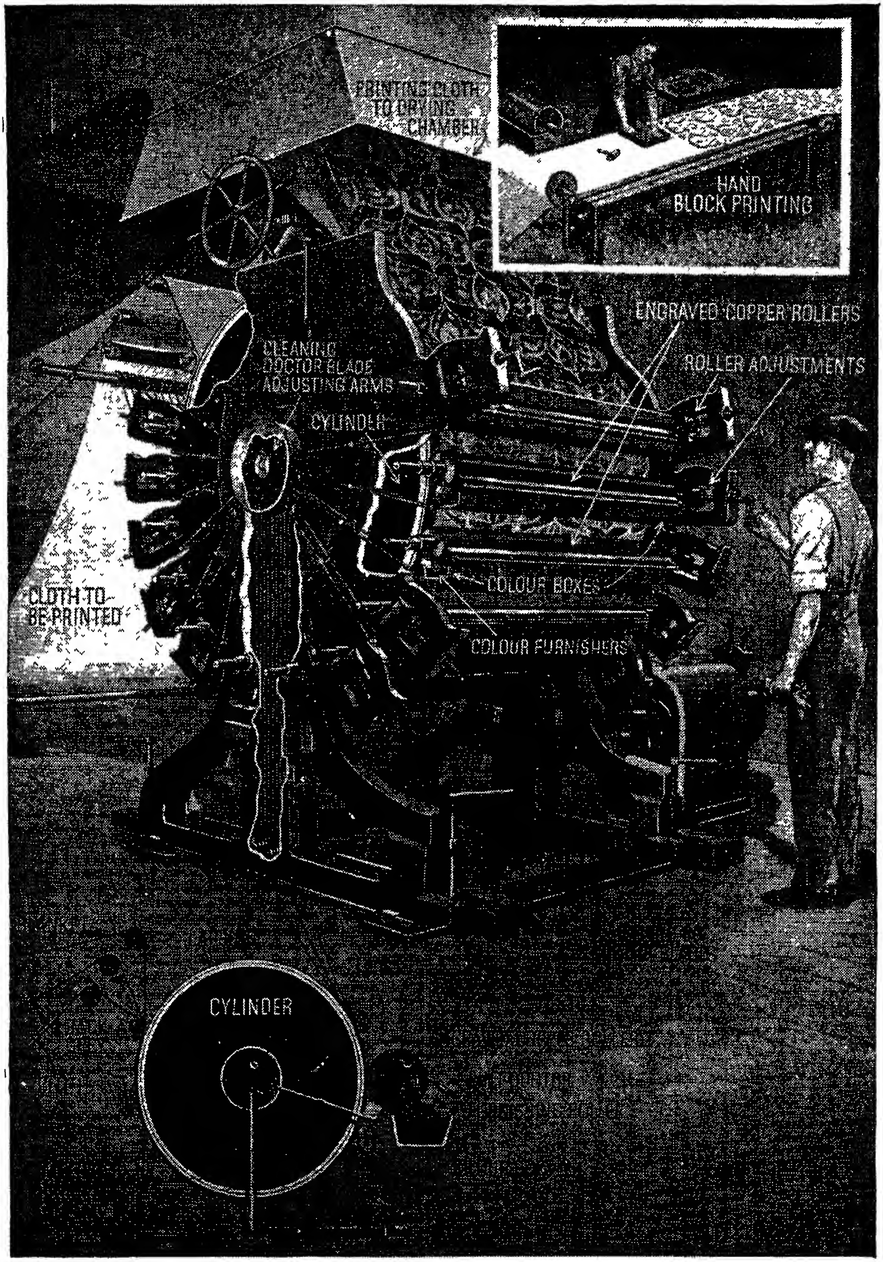
The cloth finisher obtains some wonderful effects by giving fabrics special characteristics as a result of modifying their feel and appearance. Cloth-finishing has been described as the art of cloth development. In some instances the work is slight and confined to washing, pressing, drying and smartening the product of the loom without substantially altering its main feature. In other instances, the finisher's work is revolutionary in its results, and the finish gives the cloth a new and distinctive character. After the bleaching, dyeing, and printing operations some cotton fabrics are limp and raggy, and methods are adopted to improve them. Cotton cretonnes are usually given a good coating of starch, followed by drying, damping, and calendering. Prints and shirtings are also improved to the touch by a starching process. Flannelettes, winceyettes, and similar fabrics are finished with a soft fibrous surface in imitation of wool. Some fabrics require little more than a mere scratching of the surface; others are given a thick nap almost equal in effect to that which we find on the softest wool flannels.

To some cloths, a glaze or lustre is imparted by calendering. Cotton sheetings, handkerchiefs, and table damasks are often given a beetled finish, that is, they are pounded with wooden beaters, a process which flattens the yarns and closes the spaces between the yarns of the woven fabric. Then there is the anti-crease process which endows cotton fabrics with the resilience of wool.

"Commission trades"

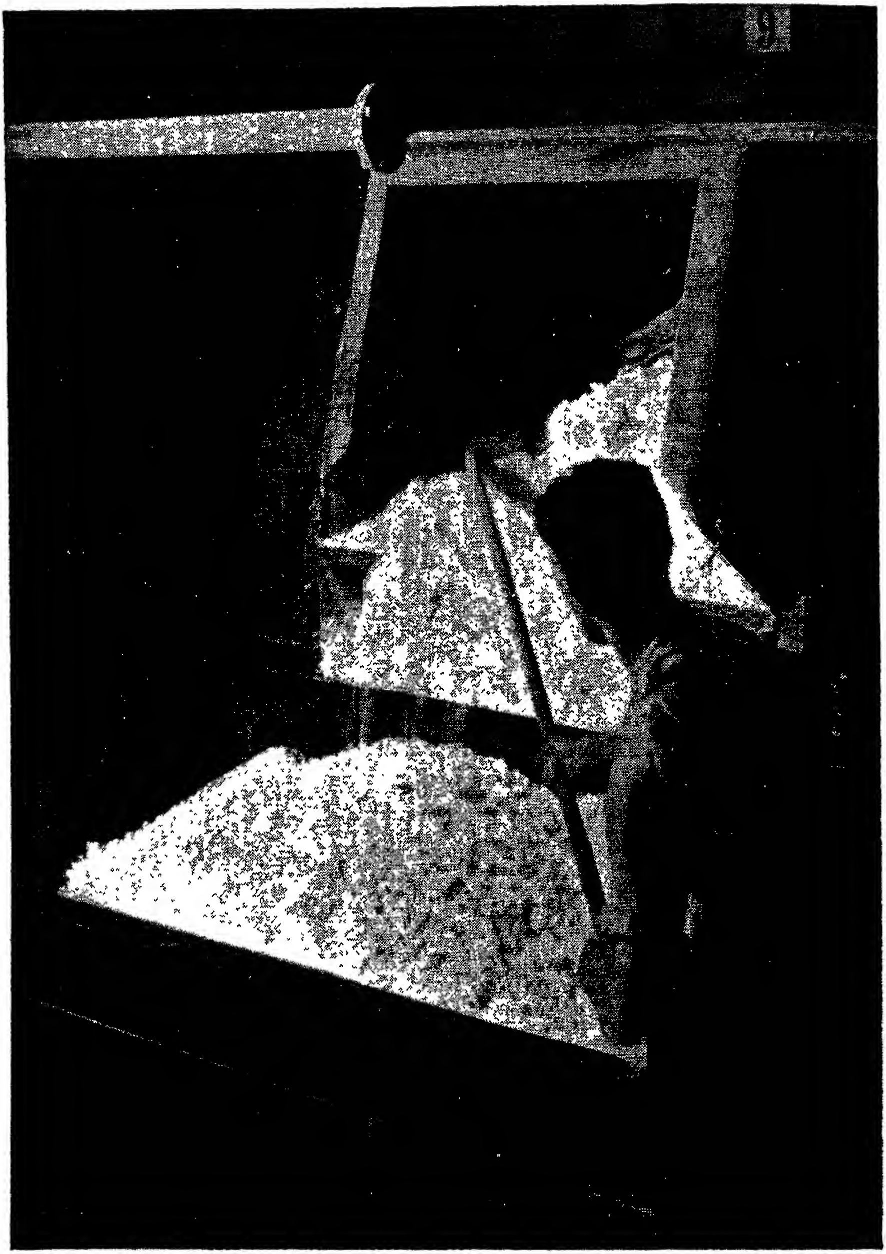
The finishing trades are known as "commission trades;" alternatively they are said to work "on commission." This means that the cloth, or yarn, treated by the finishers does not become their property but remains the property of the merchant concerned, to whose detailed orders it is bleached, dyed, or printed, as the case may be, and to whose warehouse it is returned.

When the manufactured cotton goods have been through the finishing processes they are sent to the shipping merchants for export, or to the home trade merchant for distribution in Britain. Thus, after having been passed through many hundreds of processes, the cotton fibre is ready in the form of threads, lace, hosiery, woven goods, and garments, for the ultimate consumer. Cotton is Lancashire's industry, and Lancashire's industry is one of Britain's greatest. It has been built up by the skill, initiative, and ingenuity of Lancashire folk who think in terms of cotton and take a justifiable pride in their traditional trade.



HOW COTTON IS PRINTED

FIG. 7. *Two methods of printing cloth—mechanically and by hand—are fully demonstrated in this drawing. Though the newer method is infinitely the swifter and more productive, traditional hand-block printing produces effects of an individuality as yet unsurpassed in their particular sphere.*



CRUMBS TO MAKE RAYON

After mercerizing treatment in a bath of caustic soda, the alkali-cellulose is subjected to hydraulic pressure to squeeze out surplus moisture and is then ground into crumbs, which are seen in the above photograph being collected from a shredder preparatory to being stored and "ripened" for use in closed boxes under exactly controlled conditions of heat and moisture.

ROMANCE OF RAYON CREATING NEW FABRICS

By Arnold Hard

Rivalling the silkworm. How Rayon came into being. From wood pulp to dress length. "Crumbs and syrup." Ageing the viscose. Spinneret process explained. Washing and bleaching the cakes. Acetate and cuprammonium processes. Definition of technical terms. Fabrics from Rayon staple. Nylon—its possibilities.

It is probably correct to say that every man, woman and child in every civilized country wears or uses something of rayon every day. Most dresses, lingerie, sportswear and women's slumberwear worn nowadays are made from it, as are furnishing fabrics, ribbons, smallwares and haberdashery goods.

It may be described by a trade name such as "Celanese;" "Courtaulds," "Bemberg" or "Fibro;" by a term like "Staple Fibre," or by a prefix "Spun" or "Art." If one sees a fabric described as "Art." one can assume it to be rayon. The "Art." is an abbreviation of "Artificial Silk" the name coined by its inventor, Sir Joseph Swan, of Edison Swan fame. It must be remembered that he did not carry out his experiments to produce a new textile but to give to the world electric lighting. His first rayon was nothing more than collodion, or gun cotton, made into a filament by being squirted through a hole. When it was rubbed it gave off little pops. However he soon found a way of denitrating it and rendering it non-explosive. He made filaments for electric light bulbs, but the ladies of his household crocheted up the former into very attractive doyleys (the first doyleys so made are preserved at South Kensington). Electric lighting was conceived and rayon was born.

To-day rayon is made finer than any silkworm can produce. It is also made stronger than cotton, as cool as linen or as warm as wool. A textile in its own right, it is neither an artificial anything nor a substitute for any natural filament or fibre.

What is this magic man-made thread which weaves richness and beauty into every kind of fabric?

Cellulose for Rayon

There are several types but the majority are produced from cellulose. What is cellulose? It is the substance of all vegetable tissue. The smallest blade of grass and the greatest forest tree contain it. We eat it, wear it, make from it paper, films, nail varnish, dope for aeroplanes, "Cellophane," paint for cars and a whole range of moulded goods. Being a solid it has to be reduced to a liquid before rayon can be manufactured from it.

The best cellulose for rayon is obtained from the gleanings of the cotton fields and from the second ginning of the cotton-seed (whereby linters are produced) and from fir, beech and hemlock trees. ("Ginning" is the separation of the cotton seeds from the fibre, the "linters" being the covering left on the seeds of some varieties after removing the spinnable cotton.)

The trees are felled and cut into logs which are stacked to season. The logs are cut into lengths and all dirt and bark removed. Powerful chopping machines

reduce the lengths into discs of about one inch which in turn are broken into chips. The chips are fed into digesters each holding from 10 to 40 tons, and are boiled under a pressure of about 80 lbs. in a liquor consisting of a solution of calcium bisulphite with an amount of free sulphur dioxide. The boiling separates resins, gums and other impurities and leaves the chips looking like small white fibres. After further washing, scouring and bleaching the pulp, as it now is, is spread out as a thin sheet on an endless wire cloth and water passed through it to make quite sure no impurities remain. The wet pulp is pressed into a damp sheet between felt-covered rollers, and passed through a succession of other rollers and heated drying cylinders, finally emerging looking like coarse blotting paper. It is then cut into convenient sized sheets and baled ready for shipment to rayon factories.

Rayon-producing centres

The chief rayon-producing centres in the United Kingdom are at Aintree, Bury, Coventry, Doncaster, Flint, Golbourne, Holywell, Jedburgh, Lancaster, Littleborough, Nelson, Preston, Spondon, and Wolverhampton. In the ordinary way wood pulp is mainly used for viscose rayon, and cotton linters for acetate and for cuprammonium, but so much wood pulp is required for paper making and other purposes that the viscose rayon companies are using larger proportions of cotton linters.

Rayon being produced by man to satisfy a recognized want and being man-made is under his complete control to mould as desired. He can make it so strong that it is excellent for tyre fabrics, excellent for weaving sail cloth for racing yachts, or, on the other hand, so gossamer that it exceeds in fineness the most diaphanous eastern silk tissue. It is made to be crease-resisting and with the characteristics of every natural textile.

Let us follow its manufacture step by step by going through a viscose rayon factory using wood pulp. (This type of rayon got its name "viscose" from the fact that the wood pulp solution from which it is spun is a viscous mass, in appearance very like golden syrup.)

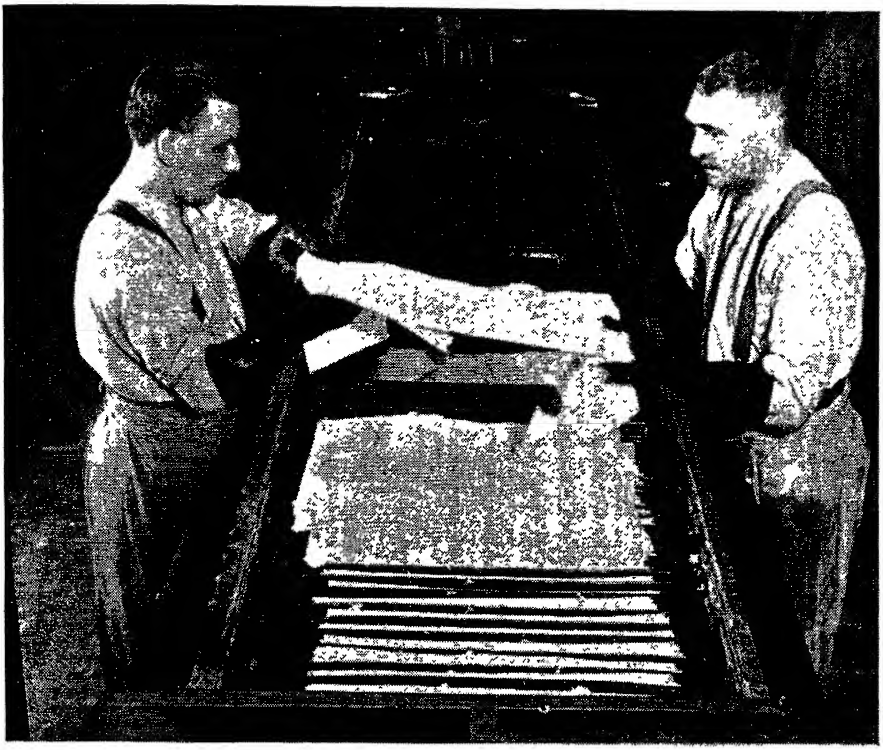
Wood pulp from Canada

When the bales of wood pulp arrive from Canada or elsewhere they are placed in a room kept at a constant temperature to maintain an even standard of moisture in the pulp. In rayon manufacture everything is controlled, nothing is left to chance (Fig. 2).

Rayon manufacture starts when the sheets are cut up and given a good bath. But they are not just put in a bath like a baby. Oh no, all the little chips after again being weighed, are carefully packed into perforated steel cradles and lowered into the bath, which contains a solution of caustic soda. The process is called mercerization after the chemist John Mercer, who studied the action of caustic soda on cotton thus inventing ways of improving cotton yarns and fabrics in look and strength. The caustic soda dissolves everything not required while the remaining cellulose combines with it and forms alkali-cellulose (Fig. 1).

From fir tree to syrup

Taken from its bath the pulp is next subjected to very rough treatment. Huge hydraulic presses squeeze out surplus moisture and great dough mixers (much like bakers use) fitted with big spiral blades and serrated bars grind it into crumbs which look for all the world like bread crumbs. The crumbs are ripened by being stored for a couple of days in closed boxes under exactly controlled conditions of heat and moisture. Next they are placed in churns with a measured quantity of carbon disulphide and churned until



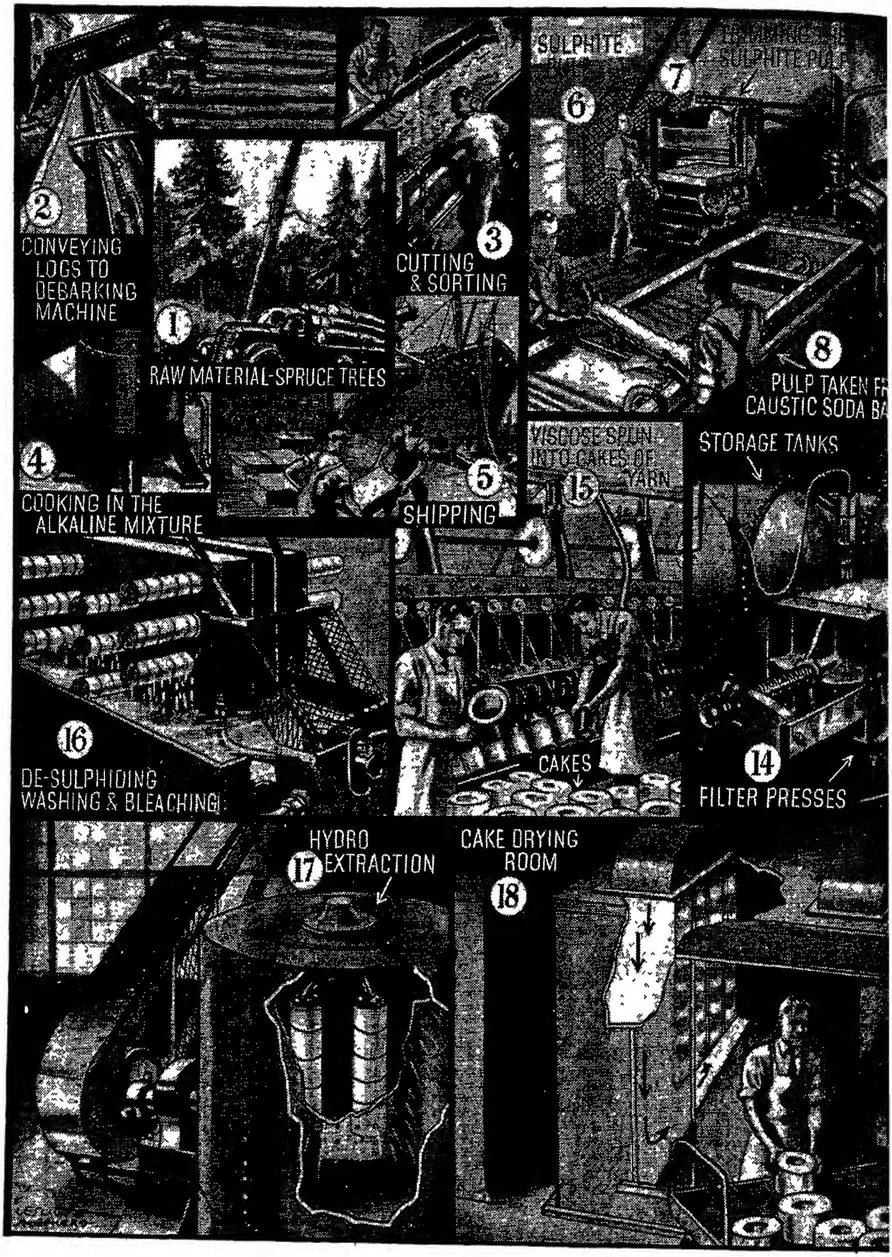
FIRST STAGE IN RAYON MANUFACTURE

FIG. 1. *Pressed sheets of wood pulp are seen being removed from the perforated steel cradles in which they have been lowered into a bath containing a solution of caustic soda. This process removes all impurities, and the remaining cellulose combines with the caustic soda to form alkali-cellulose.*

they turn yellow. The alkali-cellulose has changed to sodium cellulose-xanthate (*xanthos* is Greek for "yellow") soluble in water. The sodium cellulose-xanthate is put into mixers with water and weak caustic soda and churned until it becomes a "golden syrup." It has now become viscose.

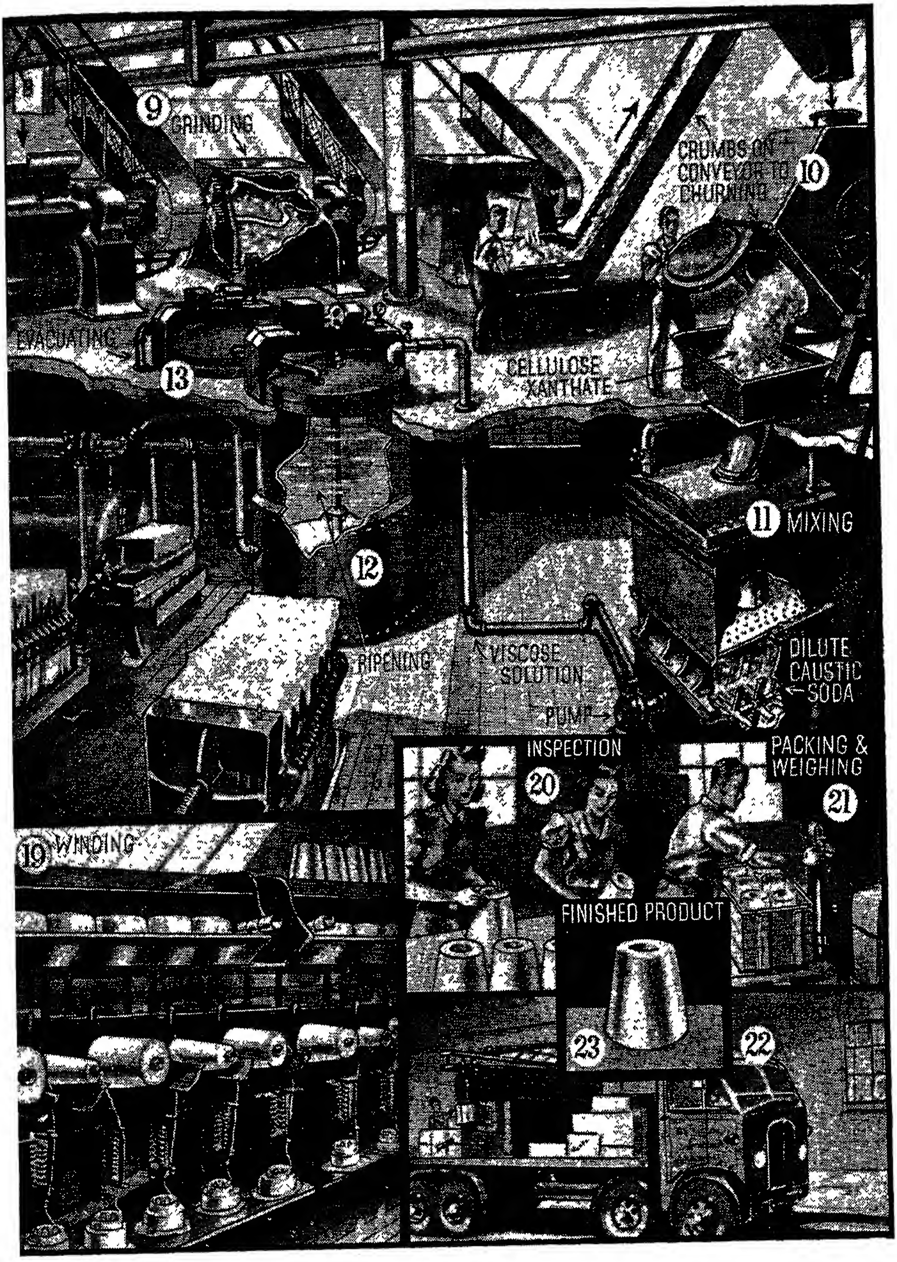
The giant fir tree in its journey from forest to fabric has at last reached a half-way house at which in pioneer days, the viscose process was held up.

Swan left the development of man-made textiles to his assistants, Stearn and Topham, who had a little works of their own at Kew. They tried and better tried to make rayon from viscose but every time stopped at the halfway house because the "golden syrup," refusing to coagulate into a thread, dropped in tears from the nozzle through which it was squirted. One day in disgust Topham walked out and left it. Next day he had another try and was surprised to find he could get short lengths of filament. (Actually he had produced staple rayon without then realizing it.) He left the syrup (viscose) another twenty-four hours and when he "spun" it was delighted to discover that it came out in a strong endless thread which emitted a musical note when twanged. He had discovered the secret of the "ageing" of viscose almost by accident. After ageing, the viscose is meticulously



FROM CELLULOSE TO RAYON:

FIG. 2. *Among the most ingenious processes invented by man is the transformation of cellulose into a material that has so many, practical uses. Main stages are shown in the above drawing, from the primary forestry work and preparation of wood pulp to loading of the finished rayon cones.*



SEQUENCE OF PROCESSES

It will be seen how each process is meticulously regulated. Great care has to be taken to prevent air bubbles or dirt specks forming in the viscose, which is repeatedly passed through cloth filters and subjected to treatment by vacuum pumps before spinning into many types of beautiful fabric.

freed from any foreign substance by being repeatedly passed through filter cloths. Vacuum pumps extract any air or gas which may have got into it, for even the tiniest speck of dirt or dust or the smallest bubble of air would interfere with the amazing process which follows.

How the spinneret works

The silkworm produces filaments by forcing a solution through minute holes in its body. Rayon is produced by forcing a solution through minute holes in a spinneret: a little cap the size of a thimble, and resembling a miniature silk hat. Spinnerets are usually made of a platinum-gold alloy and the number of holes in them decides the number of filaments in the yarn. The yardage per lb. of the yarn is described as so many denier. What is a denier? It is an old weight: 33.33 = 1 dram. A length of 520 yards is weighed in deniers to determine the count (or size) of the yarn. If 520 yards weigh 90 denier and there were 50 holes in the spinneret the yarn is known as 90 denier, 50 fils. But to resume:

The viscose is pumped through the spinneret—in much the same way as water comes out of the rose of a watering can—into an acid bath which coagulates the filaments (Fig. 3). Each viscose spinning machine has a large number of spinnerets in a row and as the fibres come from them they are drawn over a glass wheel and dropped down by a glass funnel into a rapidly revolving pot. They are thrown against the sides of the pot and wound into a form exactly resembling a cake with the middle scooped out. The diameter and speed of the pot in ratio to the delivery rate of the glass wheel determine the amount of twist given to the yarn. Pot spinning is the oldest method of rayon producing and although many other methods have been introduced it has held its own for sixty years. Legh S. Powell employed it first in 1884. His pot was a straight jar such as sweets were sold in. Charles Fred Topham, who worked with him, made an improvement by using the treadle part of a sewing machine to cause the pot to revolve rapidly. Sometime back, Mr. Powell sent a letter to the present writer, which gives an interesting sidelight on the history of our subject. It contains this remarkable sentence: "The other day I was kindly invited to visit the —— Lamp works . . . Accompanied by my daughter (I, after lapse of many a long year, she for the first time) saw the glossy ever-lengthening thread slowly descending the tall cylindrical jar and coiling up. It is a fact that away back in the eighties the Company erected the building and my process has been carried on in it ever since."

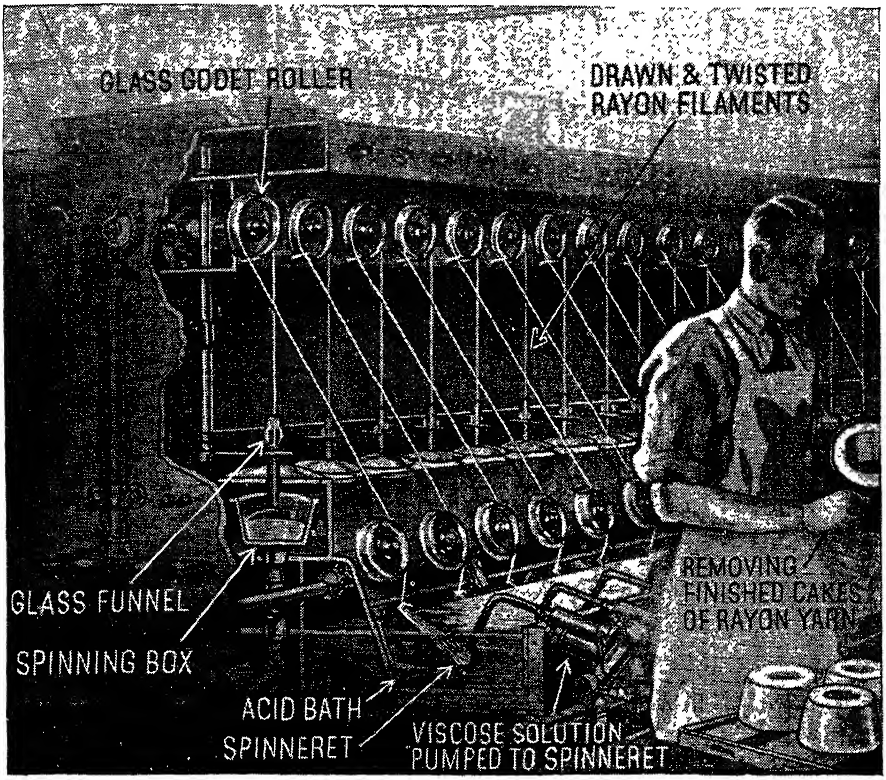
The "cakes" of rayon are taken from the pots, washed with sodium sulphide, sprayed and bleached. They are then wrapped in stockinet, in the same way as New Zealand lamb, and are dyed under pressure. An older method, still largely employed, is to unwind the filaments from the "cakes," re-wind them into hanks and dye the hanks. The extreme care taken in washing and bleaching preserves the whiteness so that yarn can be dyed in the most delicate shades (Figs. 4 and 5).

For weaving the dyed rayon is wound on to beams for the warp threads and on to pirns (which go in the shuttles) for the weft threads. For hosiery or circular knitting it is wound on to large cones.

In the acetate process, the solution is forced through the spinnerets and down tubes up which warm air travels and sets the filaments. The setting of the filaments by air is actually the silkworm's method.

Cuprammonium process

In the cuprammonium process the cellulose is dissolved by the use of an ammoniacal copper solution. The cuprammonium process was first used in London by Arnold Spiller. In a letter to



SECRET OF THE SPINNERET

FIG. 3. *Viscose solution is pumped through the spinneret into an acid bath. This coagulates the filaments which are drawn over a glass roller and dropped by a glass funnel into a spinning box where the cake of rayon yarn is formed. Next, the yarn is washed, bleached and dyed for weaving.*

the writer, Mr. Spiller gives some interesting details:

"It was in 1885 that I produced filaments by the cuprammonium process but I do not claim any great credit for this, my contribution to the development of rayon. Years before, John Mercer had dissolved cellulose in cuprammonium, recovering it with acid, and so when I made my little experiment it was thoroughly well known that cuprammonium was a solvent for cellulose, and I was always surprised that neither Swan nor Powell had tried it for their filaments. Powell had constructed apparatus which made filaments wound up into a sort of ball and all I did was to feed his apparatus with cellulose dissolved in a solution of cuprammonium instead of zinc chloride. At the time I was chemist in the —— Company's incandescent lamp department, of which Mr. Powell was superintendent. I made my experiment as a matter of interest to see if an aqueous cuprammonium solution would produce better filaments than chloride of zinc, but as it did not, we did not do anything more with it. It must be remembered that we were making filaments for electric lamps, not for fabrics, otherwise we might have realized the possibilities of the bright, soft filaments we got. It certainly never occurred to us

HOW RAYON IS REELED

FIG. 4. *Cakes of rayon from the spinning machines undergo many processes before the yarn is fit for weaving or knitting. First, the rayon goes to conditioning cabinets, where it is toughened and hardened, and then the cakes are unwound. Above is seen how the cakes are reeled to form hanks.*

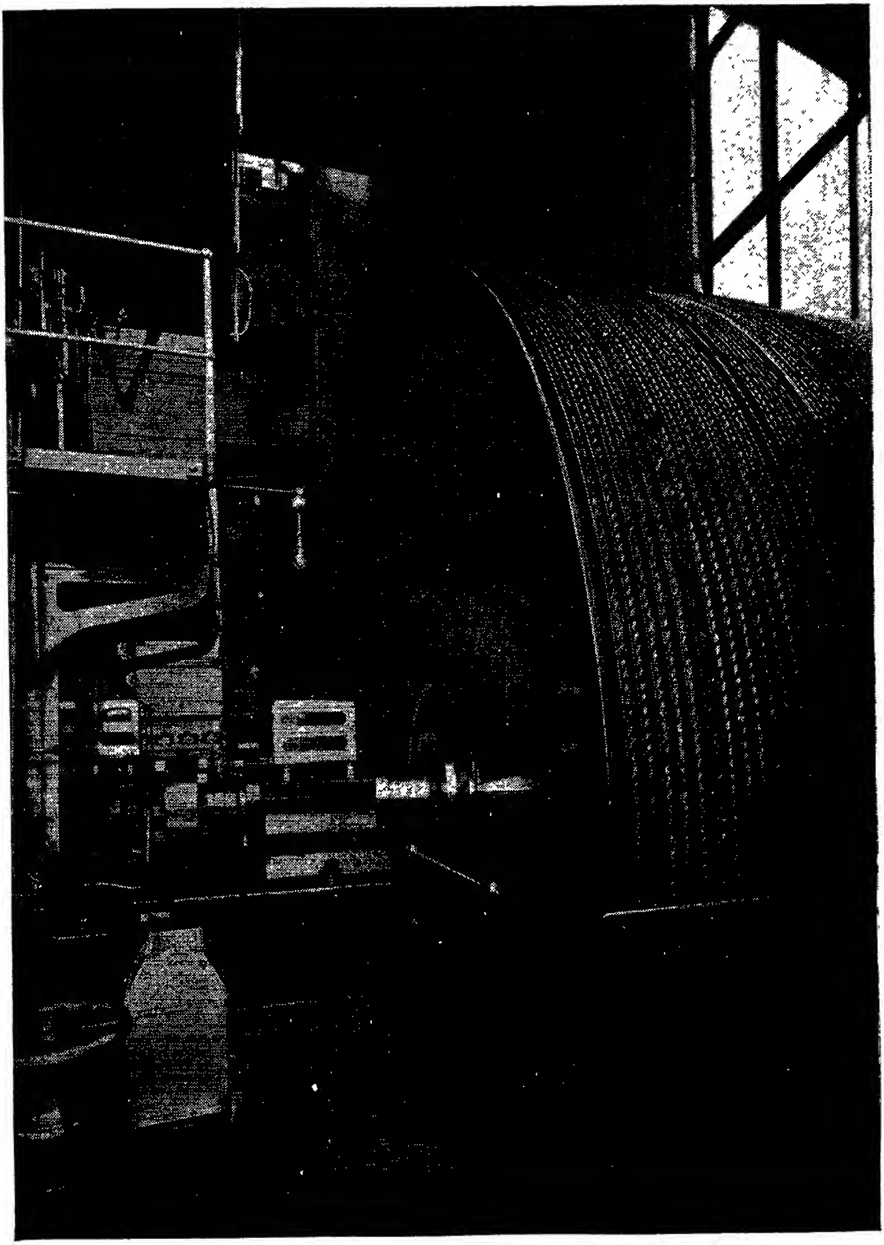
that in a few years some of the loveliest fabrics in the world and some of the most delightful knitted wear would be made from yarn produced by the process which I started so unpretentiously."

We have followed the production of continuous filament rayon from the pine forests or cotton fields to the stage where it is a yarn ready for weaving or knitting. Before dealing with other types it is advisable to understand exactly what they are. In official terminology, Rayon is "all yarn and fibres not of natural growth which are used for textile purposes." Similarly Rayon Yarn is defined as continuous filament rayon yarn; Rayon Fabrics, as fabrics made from rayon yarn; Rayon Waste, as waste from rayon yarn; and Rayon Staple, as rayon staple fibre. Again, Spun Rayon yarn is yarn spun from Rayon Staple; Spun Rayon Fabrics, as fabrics made from Spun Rayon Staple; Spun Rayon Waste, as waste coming from Rayon Staple and also from Spun Rayon Yarns.

Staples, the fibres from which thread is made, have ever brought Britain prosperity. First staple wool, then staple cotton and now staple rayon have proved great commercial successes.

Rayon Staple

Rayon Staple, which is filament rayon cut into short lengths, can be spun exactly the same as wool and cotton and cut to their staple lengths. Its manufacture is similar to that of continuous rayon up to the point where the filaments are coagulated. In the case of staple rayon a large number of filaments are gathered



IN A RAYON SPINNING MILL

Here, in a staple fibre spinning mill, is seen the great rope drawing wheel and rope race that provide motive power for the machines used in successive stages of the manufacture of rayon material. Again, the enormous size of the installation, which is carefully guarded by a system of hand-rails, testifies to the "Majesty of the Machines" in our industries.

together in the form of a rope and cut to the required length of staple.

New Fabrics from Rayon

Many new fabrics are being produced from rayon staple which could not be made with natural textiles. Mixed with cotton, wool or silk, an almost limitless range of fabrics for clothes and furnishings is being woven. The manufacturer who caters for overseas markets, with their infinitely varied demands owing to vastly differing climates, has found that rayon staple adapts itself to fabrics of all weights; masterpieces of the finisher's skill are the rayon staple tweeds which bear the closest resemblance to woollen textures but which are light enough to find a ready sale in the tropics.

Spun "Fibro" on the other hand, is an article which can stand any amount of rough usage; it can be dyed faster with colours than wool fabrics; it can be boiled and rubbed; felting does not take place, nor does shrinkage. It is also mothproof.

Outstanding qualities

Rayon staple garments have quite outstanding draping qualities due to a great extent to the added weight and life put into them in finishing. They keep their freshness much longer; so one naturally asks the reason why? Rayon has a strong affinity for the dust particles in the atmosphere. It is exactly the same as can be illustrated by rubbing a piece of vulcanite, say, on fabric and bringing it close to a small piece of paper, or by the magnet drawing the steel needle to it; but the resin used in finishing the fabric has a strong resistant property and negatives that affinity.

Rayon staple, in spinning into yarn, has many advantages over natural textiles. It comes to the mill absolutely clean. It does not have to be scoured or bleached. It does not have to be sorted because all the fibres are of standard length. The usual cloud of cotton dust which hangs like a pall in mills where cotton is being combed, carded and spun, is entirely absent when rayon staple is being used.

As rayon staple can be cut to any length of staple it can be used for many purposes for which natural yarns are unsuitable. It is mixed with hairs such as goat hair to facilitate spinning. Casein rayon staple, being somewhat plastic when mixed with wool, gives a fabric which retains its pleats far better than does a fabric woven entirely of wool.

Rayon is young as an industry, yet despite its youth it has developed to an extent quite unforeseen by its early pioneers. But if, in one sense, it has "grown out of all knowledge," it is far from having reached its limit of utility and expansion in a modern world.

How Nylon is made

Nylon is quite different from rayon produced from cellulose as its base comes from gas works and ammonia plant.

The essential starting materials are phenol (carbolic acid) and ammonia, which are converted in the chemical factory into the two products adipic acid and hexamethylenediamine. These are delivered to the rayon factory in the form of a "salt."

The first stage of production is the concentration of the salt and its conversion into a rough resinous substance. This conversion is carried out in a heated pressure vessel—such as an autoclave. The material is melted, and afterwards spun and drawn. The removal of the material from the autoclave is a fairly complicated business, because it is viscous and approximately between only 10 and 20 deg. C. above solidification temperature, and this rules out the possibility of taking it to the spinning machines through a piping system. In one process the stuff is made to emerge from the autoclave in the form of a ribbon. This ribbon is taken over a

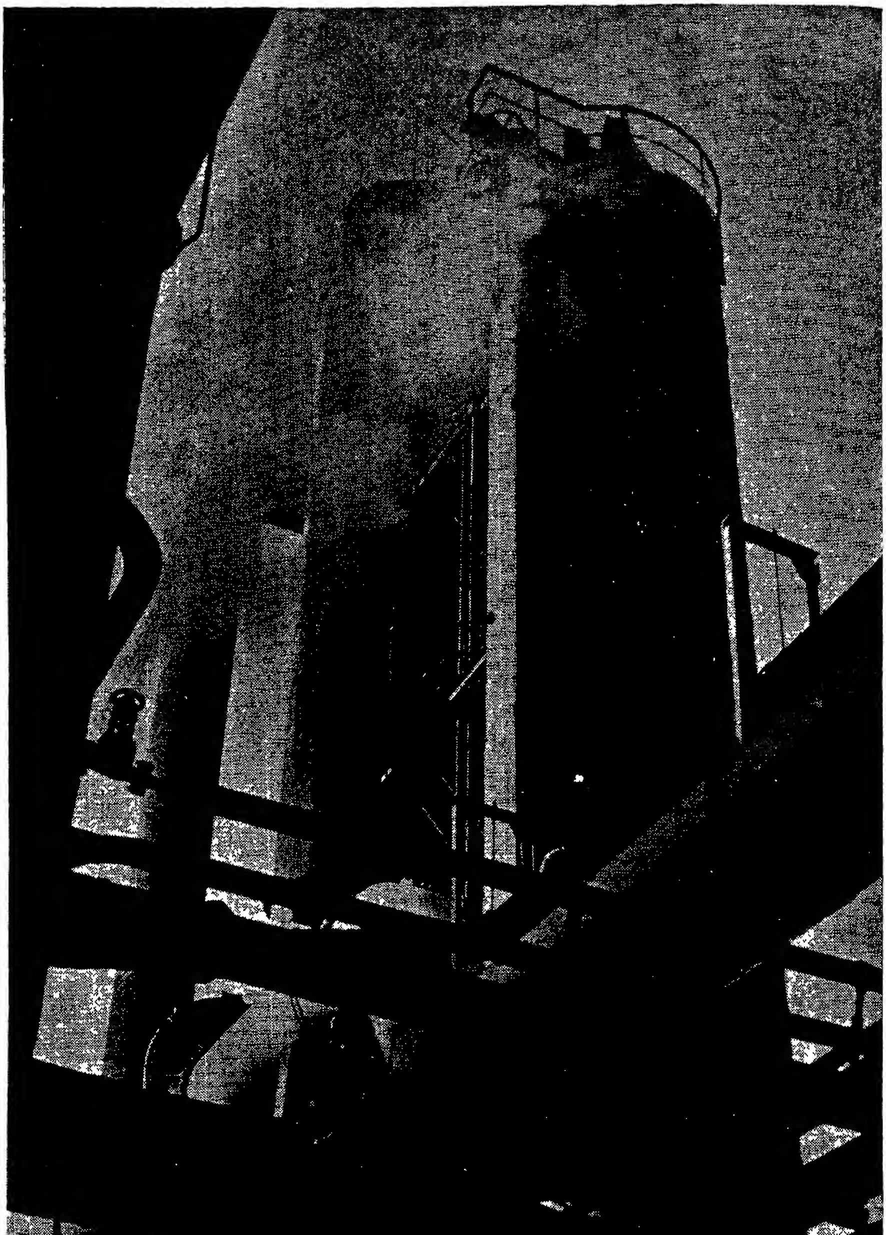
SORTING AND GRADING RAYON STAPLE

FIG. 5. *After they have been bleached and dried the hanks of rayon are sorted and graded by women workers into qualities, as is seen in the above photograph. The shaft in the roof is part of the air-conditioning plant, which ensures the requisite amount of humidity.*

cooling drum, and as it passes round the drum is sprayed with water. Alternatively, the ribbon may be taken through a trough of cooling water. Anyway, after being cooled the ribbon proceeds to a dryer. Later, the material is punched out into little pieces, and then melted in a heated chamber in which there is a coil or grid. The flakes melt when they come into contact with the grid. The next item is spinning. In one process the material leaves the heated chamber in the form of a liquid thread which is passed through a cooling chamber. After this the thread goes through a cell into which a wisp of steam is fed. Directly afterwards it comes into contact with a finish-applying roller, and then proceeds to feed-rollers and bobbins. As may be expected, the draining and air venting of the steam equipment used in the processes have an important bearing on efficient manufacture and is carefully supervised.

Uses of Nylon

The uses to which nylon can be put are multitudinous. It is immensely strong. For instance, the tow rope of the first Atlantic glider train from Canada to England is a nylon rope only one inch in diameter. But this is not all, and apart from fabrics for clothing, threads for stockings, bristles for brushes, grades for mixing with wool and silk, all of which are in use to-day, further experiments will carry the product into other fields.



MAJESTY OF MODERN INDUSTRY

In this exterior view of benzole scrubbers is powerfully symbolized the might and majesty of modern industry. It is in such scrubbers that gas is washed and debenzolized; the benzole being recovered and refined to make motor spirit. In such wise are valuable by-products rescued.

POWER AND HEAT FOR HOME AND FACTORY

By GRAHAM R. BAMBER, B.Sc. (Hons.), A.M.I.Mech.E.

From coal to electricity and gas. The first step—coal analysis. How electricity is produced. Majesty of the machines. "Cathedral-like calm" of mighty founts of energy. From control to operative—men on the job. Gas—how it is made and cleaned. Retorts and their function. Valuable by-products. A gasworks to-day.

WHEN Mrs. Smith lights the gas stove to cook the breakfast, Mr. Smith stokes up the kitchen boiler, and Master Smith turns on the news, the Smith family are probably much too preoccupied to bother their heads about the long chain of human labour that has made these simple tasks possible. Probably, too, when Mr. Smith arrives at the factory for his day's work, he pays little heed to the lighting, the building heating, the power to drive the machines, the gas for the furnaces, the steam for the boiling vats, or any of the essential services of a modern factory. It is all so easily taken for granted, and the only time when Mr. Smith is likely to display any interest in these matters—unless they happen to be part of his job—is when he is worried by a temporary "failure" of any of these services.

So let us go back to the beginning. In a sense, it is a black beginning, for Britain's power and heat are founded on one invaluable commodity—coal. Oil, the rival fuel, has, of course, the monopoly of road transport, but coal remains the foundation of Britain's power and heat.

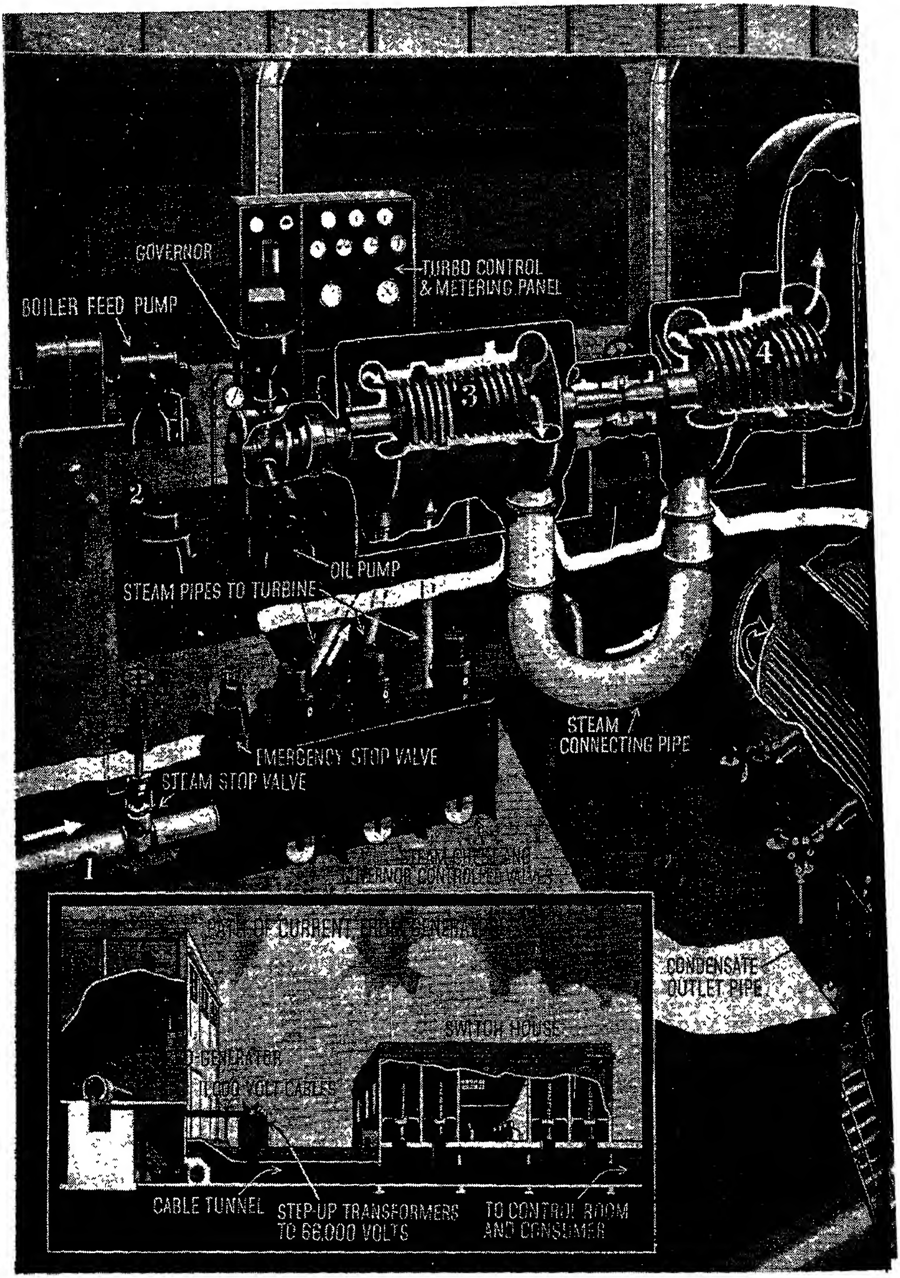
The first thing that we discover is that there is coal *and* coal; so visiting a large electric power station, we cannot do better than ask the chief chemist about this question of coal analysis.

"The chief trouble," says he, "is to get a really representative sample to analyse. You know, Mr. Smith, how much coal varies, even in a single delivery."

He takes us to the coal wharf. A coal barge is lying alongside, and a grab crane is transferring its contents to a large hopper. From the hopper the coal falls to an elevator by which it is taken to the top of the boiler house, where it is discharged to a row of bunkers located just beneath the roof and forming the entire ceiling of the boiler house. At the foot of the receiving hopper, a scoopful of coal is taken every few minutes and put in a bin. When about a hundredweight has been collected, it is put through a crushing machine and broken into pieces about a ¼ inch in size. It is then mixed evenly together, subdivided, and about 10 lb. of it taken out. These are dried, ground to a powder, mixed, subdivided, and about 4 oz. taken out from which samples are removed for analysis.

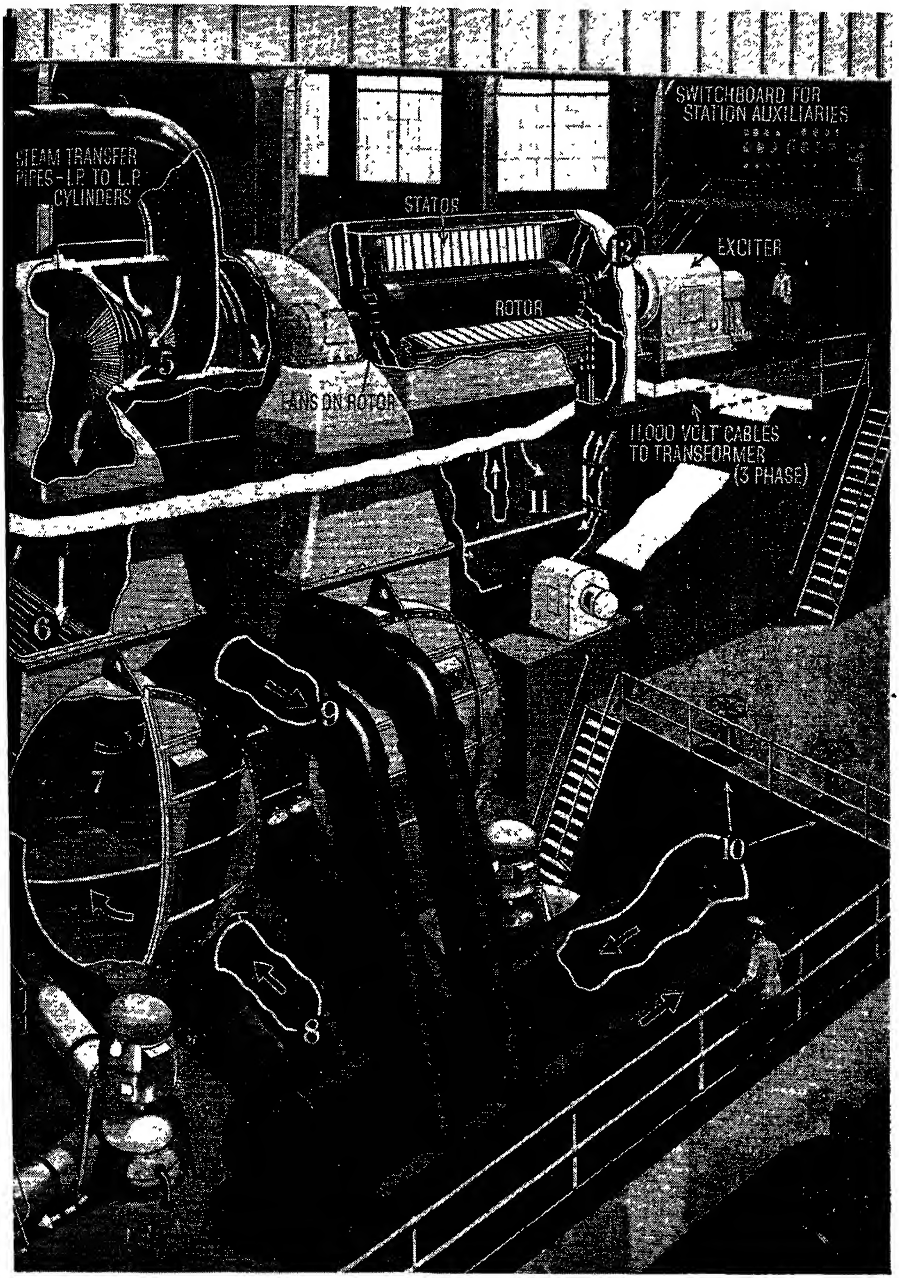
3,000,000 units daily

The boiler house superintendent tells us that the power station burns about 1,400 tons of coal in a day. "We are carrying a load of about 130,000 kilowatts at the moment, and we turn out about 3,000,000 units a day." We enter the boiler house and, except for a low rumble of machinery, we find the peace of a cathedral.



HOW ELECTRICITY IS PRODUCED:

FIG. 1, *above, shows a typical turbine house, where electricity is generated by steam turbines. Key to numbers: 1, superheated steam pipe from boilers; 2, main valve governor; 3, high-pressure impulse cylinder; 4, intermediate impulse cylinder; 5, double-flow low pressure cylinder.*



100,000 KILOWATT TURBO-ALTERNATOR

Continuing, we have: 6, steam passing over the water tubes of the condensers; 7, water circulating through the condensers; 8, circulating water inlet pipe; 9, circulating water outlet pipe; 10, water control valves; 11, closed circuit air cooling system for generator; 12, slip rings.

Apart from a comfortable warmth there is little to indicate the presence of several colossal fires; but when our guide draws back a small flap in the side of one of the boiler casings we behold an inferno. The grate is mechanical and is slowly carrying the fire to the back of the furnace. As this happens, fresh coal falls on to the grate from the hopper in front of the boiler, and ash falls over the back of the grate to an ash hopper in the basement. The coal supply is varied by altering the speed of the grate. Air is supplied by powerful fans.

Running the boilers

Here and there a man is standing quietly, glancing now and then at the large instrument boards one of which is placed near each of the boilers under his care. A fireman explains that his first duty is to see that his boilers supply just the right amount of steam however the load on the station varies. A pressure gauge has to be kept at the required pressure and a steam meter shows how much steam the boiler is producing. Some modern boiler plants are controlled automatically, and this relieves the fireman to attend more fully to his supervisory duties. Then again must coal be burnt economically, and instruments check combustion.

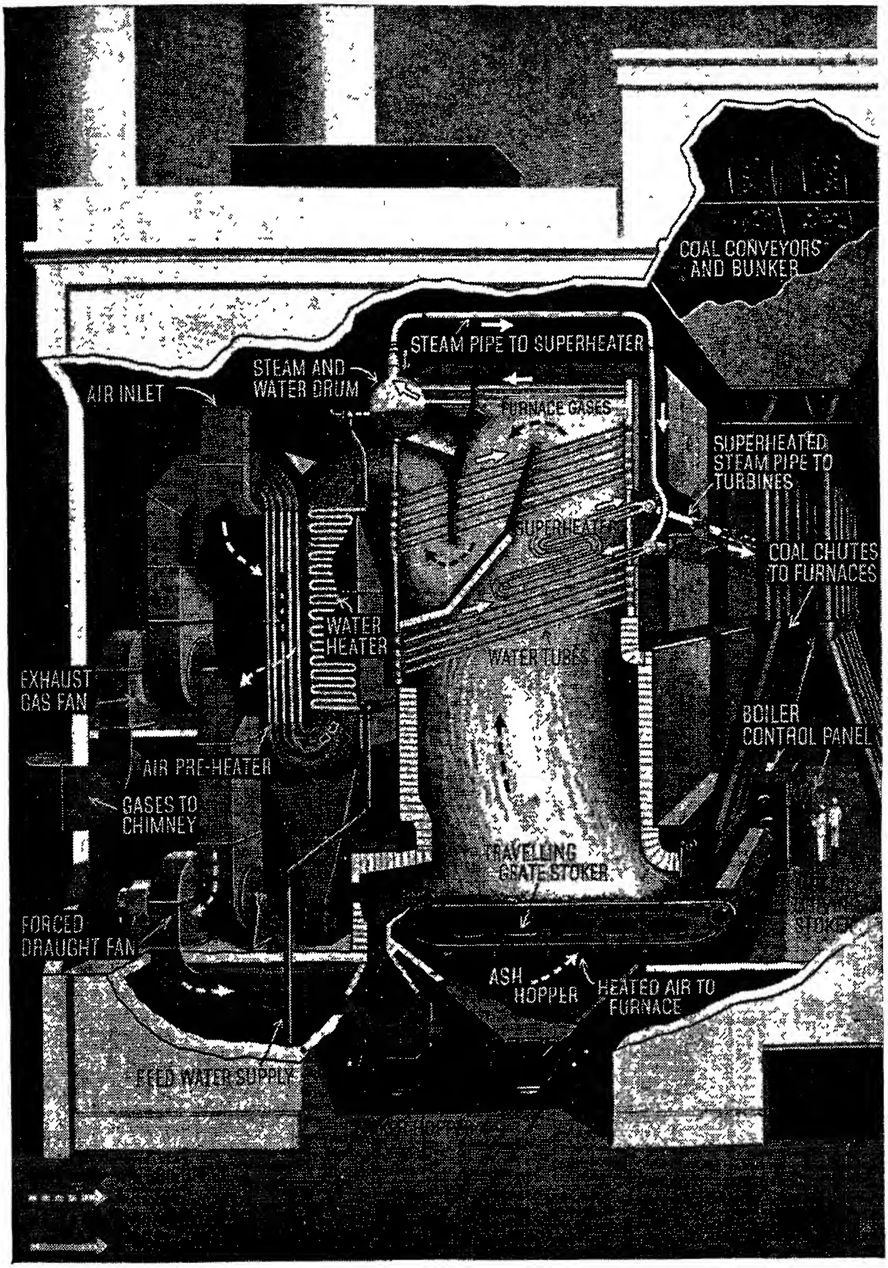
Instructions on that point come from the combustion engineer who studies the coal analyses given him by the chemist.

How long is a boiler allowed to run? "We usually take each boiler off the line every three months for sooting and give it a complete overhaul every twelve months. To put a boiler back into service we like to take about twelve hours to avoid temperature strains, although we can bring it up much quicker if we are in a hurry. Some power stations fire their boilers by pulverized fuel, and they can get a boiler on the line in four hours if need be."

"Now we'll get hold of the station superintendent," resumes our guide. "He's the chief, of course." The station superintendent rings up for the shift engineer to conduct us on our tour. "The shift engineer," he explains, "is in charge of the actual running of the station during his shift, and you may find him anywhere, from the coal wharf to the switch house."

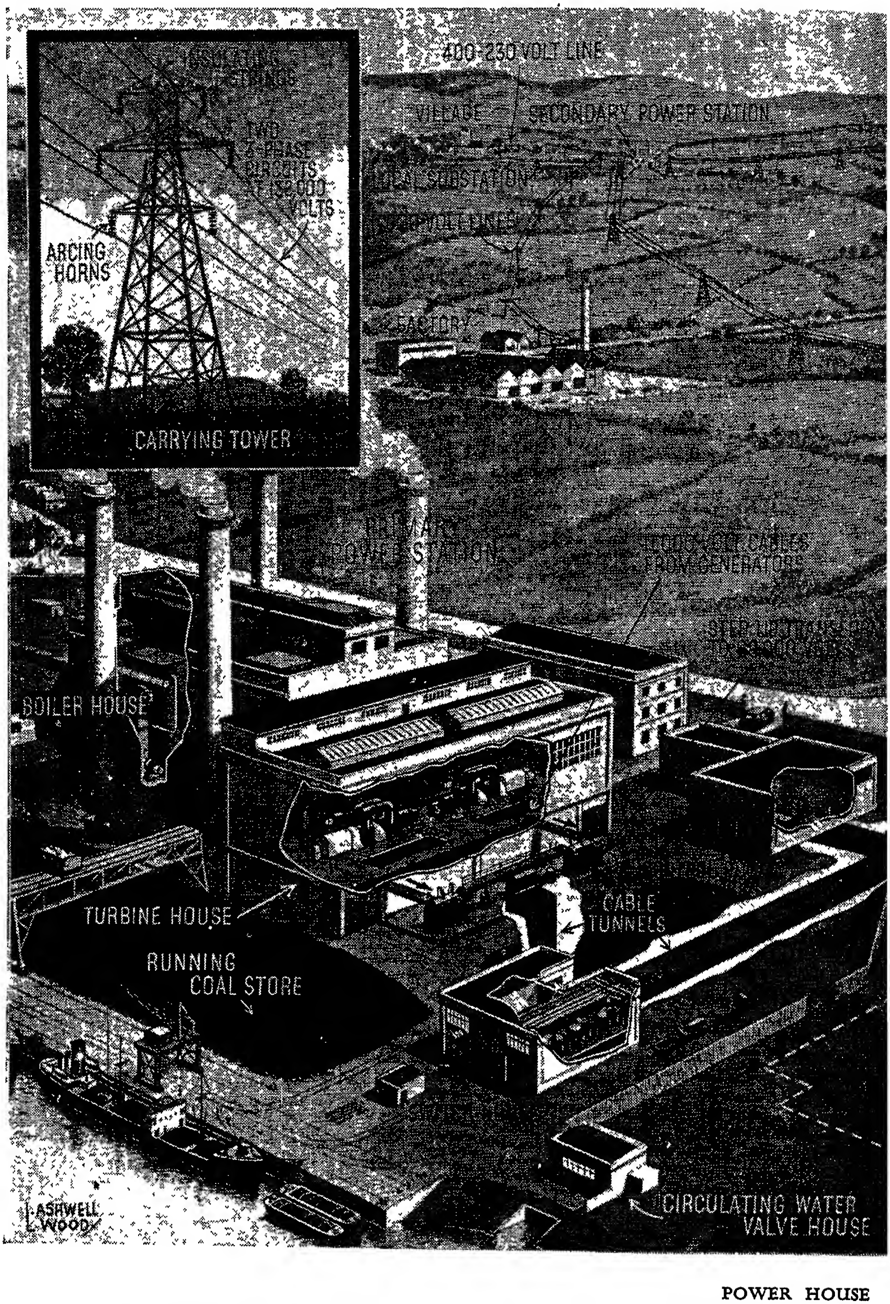
Our new friend the shift engineer takes us down to the turbine house—a vast hall, peaceful as the boiler house, except that the low rumble of machinery has swollen to a deep-throated roar from the mighty turbo-alternators ranged down the length of the hall (Fig. 1). "These sets are rated at 50,000 kilowatts each," says the shift engineer; "that's 67,000 horsepower. Of course, they'll take an overload; we can turn out well over 300,000 horse-power all told if we want to. Oh no, there are quite a few sets bigger than these. London has some 100,000 kilowatt sets." At first sight the turbine house seems unattended, but history repeats itself, and we discover an overalled figure contemplating a boardful of steam gauges, and a second examining a thermometer on one of the turbine bearings. These are the turbine drivers.

We adjourn to the control room. The ceiling consists of a large lay-light; a switchboard extends down the whole side of the room. Further switch panels occupy the ends of the same room, and one or two panels are on the back. The switchboard attendant sits at a desk adorned with telephones, and fills up a logsheet of meter readings given him by his junior. This is the nerve centre of the power station. Here are four generator panels controlling the four turbo-alternators. In front of each panel is an engine-room telegraph, those for Nos. 1, 2 and 4 sets pointing to "on load" and that for No. 3 set to "shut down." Then come switch panels for transformers, inter-connectors, grid feeders, and, finally, for a host of main feeder cables taking power to all parts of the city, as is indicated in the specially made drawing in Fig. 2.



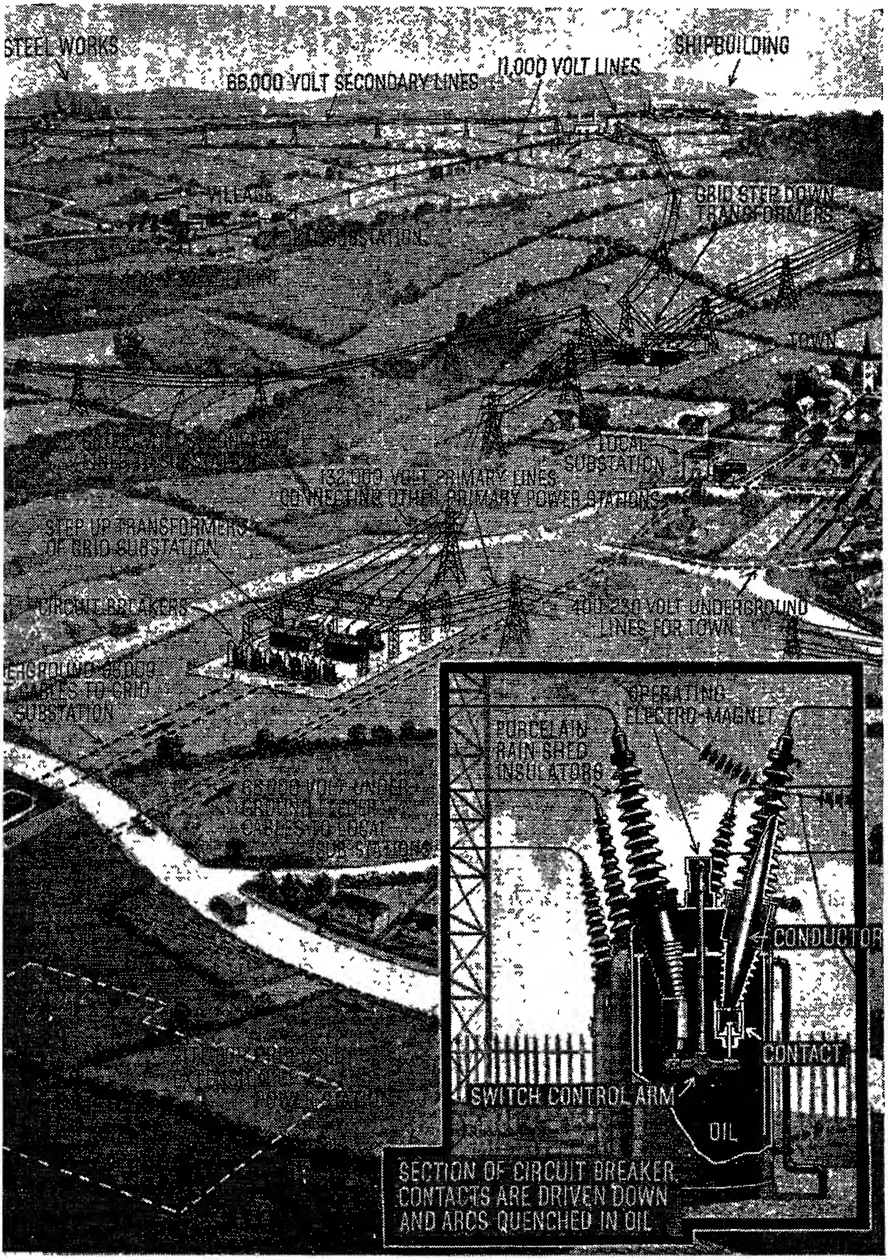
BOILER HOUSE IN SECTION

A section of a coal-fuelled boiler, such as raises the superheated steam necessary to drive the turbines illustrated on pages 186-187, is shown above. Coal supply, which is drawn into the furnace by means of a moving grate, can be regulated automatically as the demand for steam varies.



POWER HOUSE

FIG. 2. *To give an idea of how electric current is disseminated to town and village by the National Grid System, this drawing of an imaginary Power Station in an imaginary landscape enables the reader to follow all the more spectacular aspects of a process of great importance to the public.*



TO CONSUMER

In insets at the top left and bottom right of the drawing are given closer details of the carrying towers or "pylons" which carry the cables over vast tracks of the countryside; and of the circuit breakers, here cut away to show various details, not otherwise visible, of the internal mechanism.

Along the top of the switchboard is a giant circuit diagram, the switch symbols of which set themselves as the respective switches are operated.

This is not strictly a switchboard but a control board; the actual oil switches are in the switch house just behind the control room, and they are remote-operated from the control board. We take a peep into another great aisle filled with strange-looking steel giants which are the oil switches. The switchboard attendant's work is largely a matter of watching the load, seeing that it is properly shared between the generators, keeping a log of all important readings, and being ready to act at once in the event of an emergency. The frequency of the alternating current has to be kept at 50 cycles per second, but this is looked after largely by the grid control engineers, who also give a station a schedule of the load it must carry hour by hour during the day. An operation requiring the utmost care is switching a generator on to the line when the turbine driver has got it up to speed. The voltage of the incoming machine has to be adjusted until it is the same as that of the main supply, and its electrical alternations synchronized with those of the supply.

"Pick up 10 megawatts"

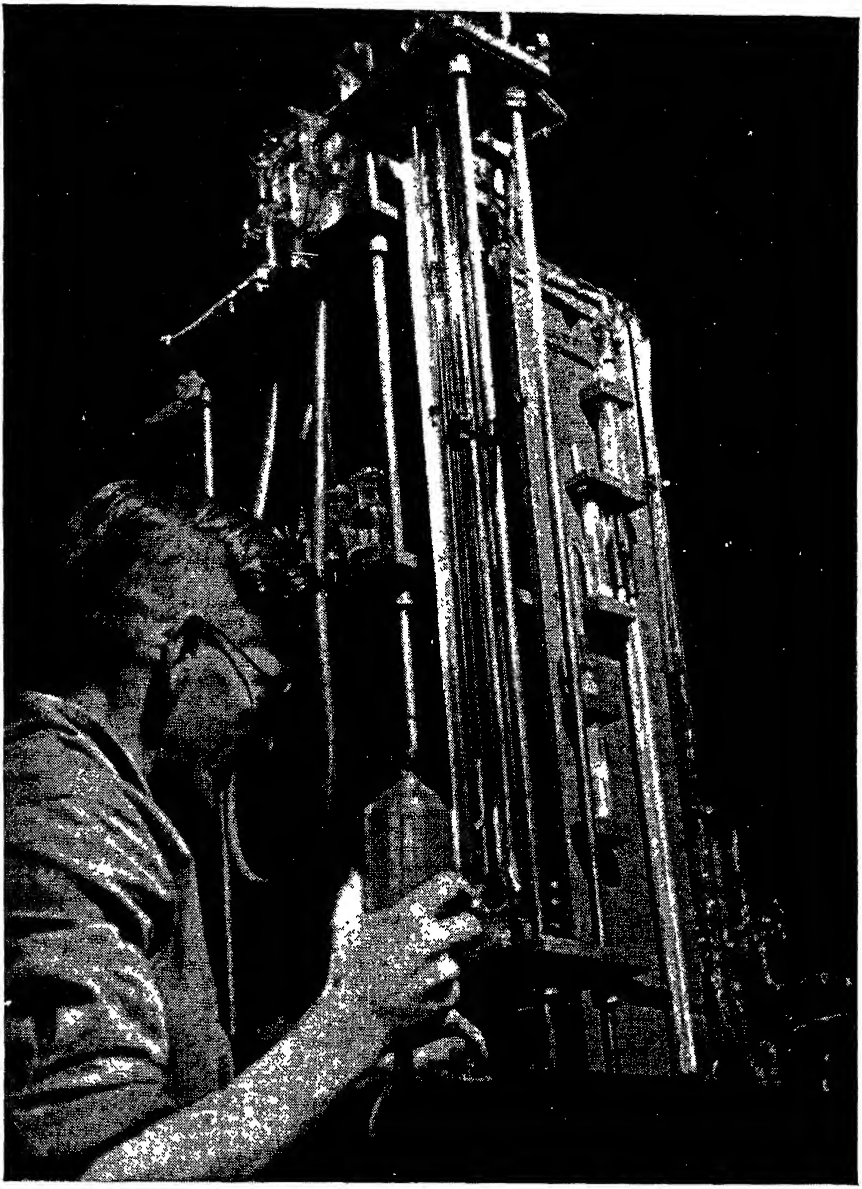
At this moment a buzzer sounds, and a panel bearing the words "Pick up 10 megawatts" lights up on a separate board at the end of the room. The attendant acknowledges it by pressing a button, and then goes along the generator panels touching a knob here and there. Instrument needles creep up; the station is taking over a further 10 megawatts—10,000 kilowatts—of Britain's electrical load. "That's from the grid area control room," our friend explains. It is suggested to us that our inspection of Britain's power supply would be incomplete without visiting the Central Electricity Board, so having obtained the necessary introduction, we present ourselves at the head offices of the Board, where arrangements are made for us to visit the national control. There a staff of engineers analyses records, estimating the nation's demand for electricity throughout the following day. This estimate is condensed into a schedule of loadings for each of the seven areas, and in due course is passed to the national control engineer in the control room.

Area control centres

Our next journey is to one of the area control centres. Here there are two adjoining control rooms, one controlling the electrical loadings throughout the area, and the other supervising all the switching operations. In the load control room two engineers are sitting at a large desk facing a wall diagram showing all the transmission lines in the district. Long-distance meters let into this diagram show the load carried on each of the main lines. One of the engineers is estimating the load for the day and allocating the necessary generation among the power stations in his area. Each power station is given advance information of the loading it will be expected to carry during the day, and the control engineers modify these instructions from moment to moment as the necessity arises.

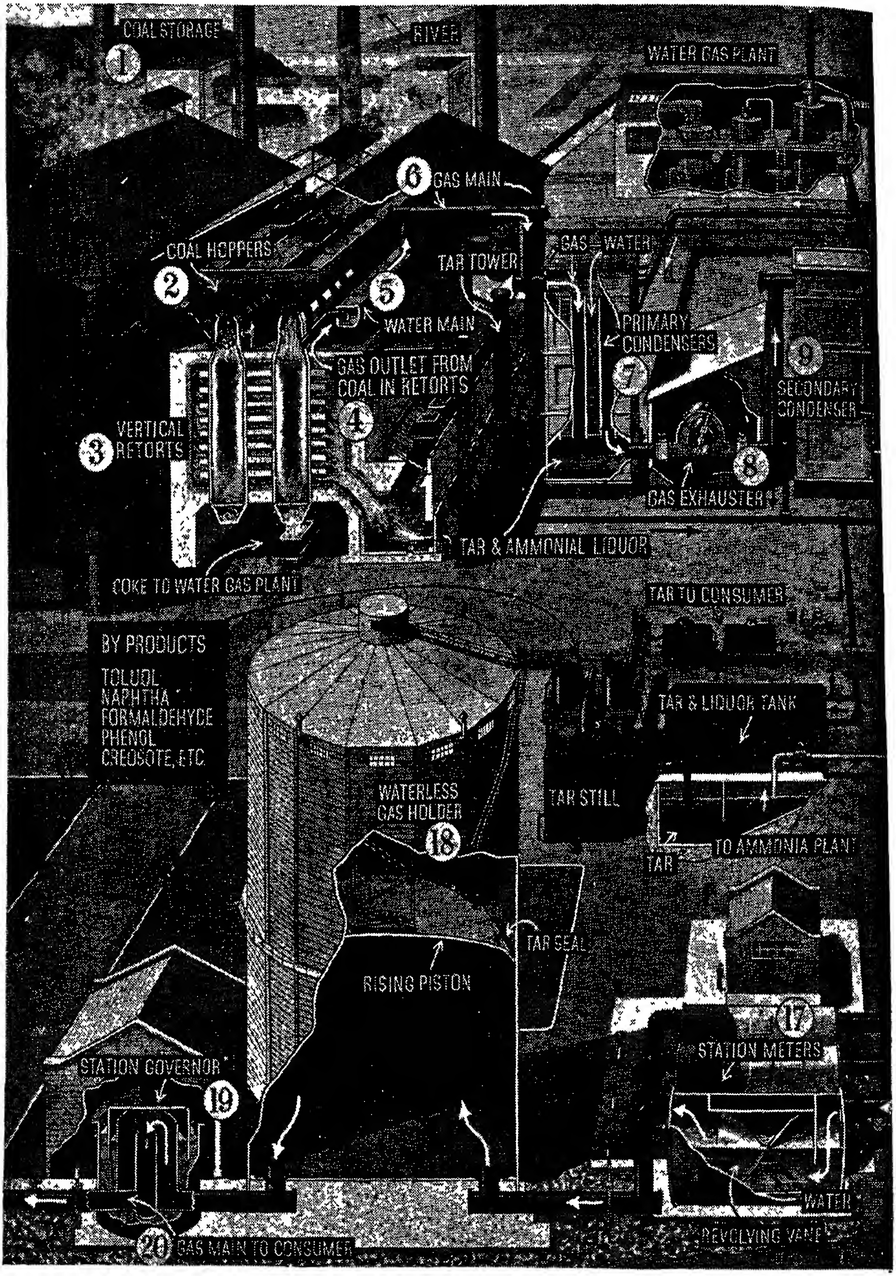
We pass to the switching control room. This is circular, and a coloured diagram of the area grid system showing every switch and every grid line covers the greater part of the wall surface. Each switch has a code number, and the switch symbol can be rotated by the finger to "on" or "off." An engineer is issuing a permit over a telephone for a certain line to be switched out for servicing. Every switching operation in the area has to be sanctioned by the control engineer.

Now let us look at that other great industry with which this chapter is concerned—Britain's widespread gas industry. Let us obtain an introduction to



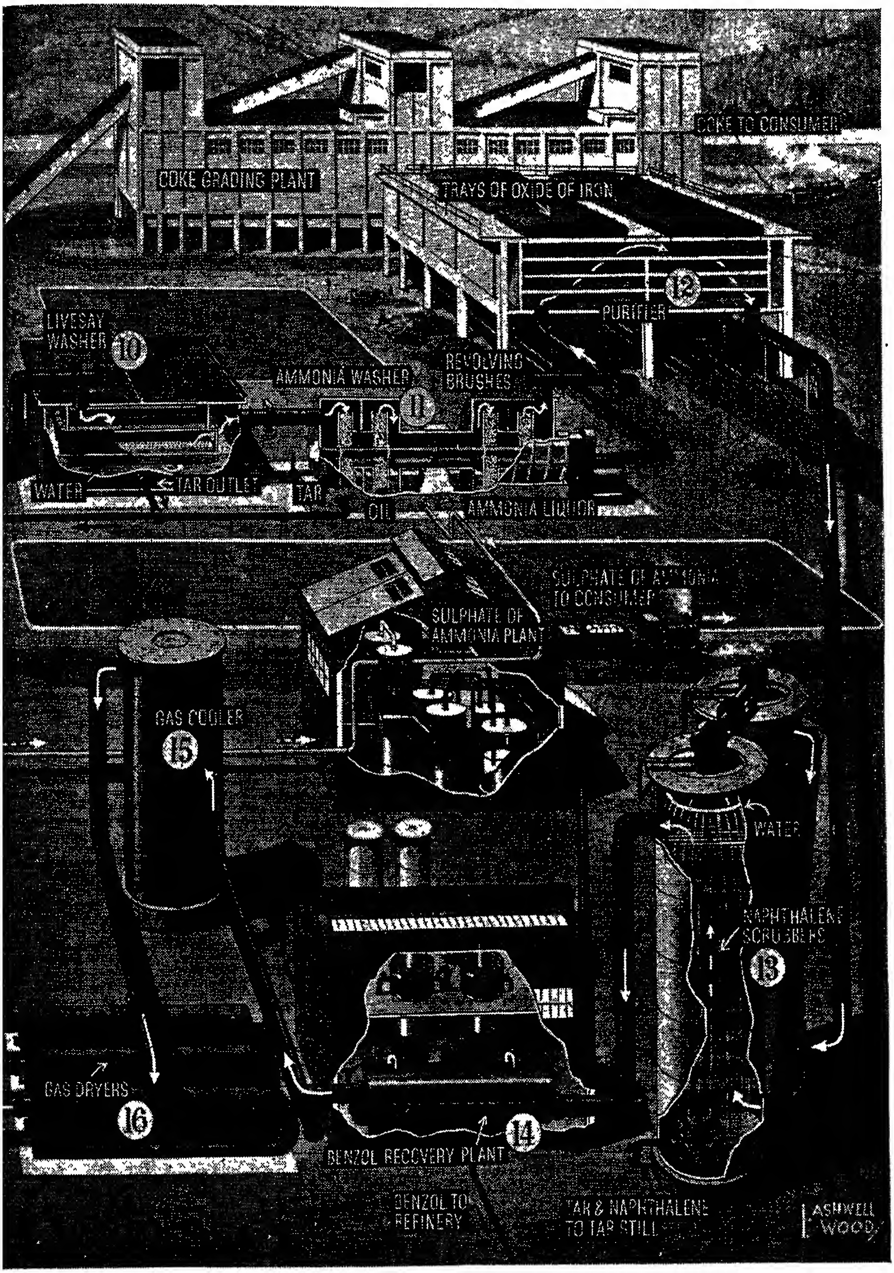
CHECKING THE QUALITY OF GAS

By daily analysis a check is kept on the composition of evolved gases to ensure efficient operation of the plant. Both the quality of gas and the method of its production are constantly studied in the laboratories so as to maintain a high standard and to search for improvement. Only by constant care and supervision can the gas, which in the first stages is a thick, brown smoke, be transformed into the "clean" household variety that burns clearly, without odour.



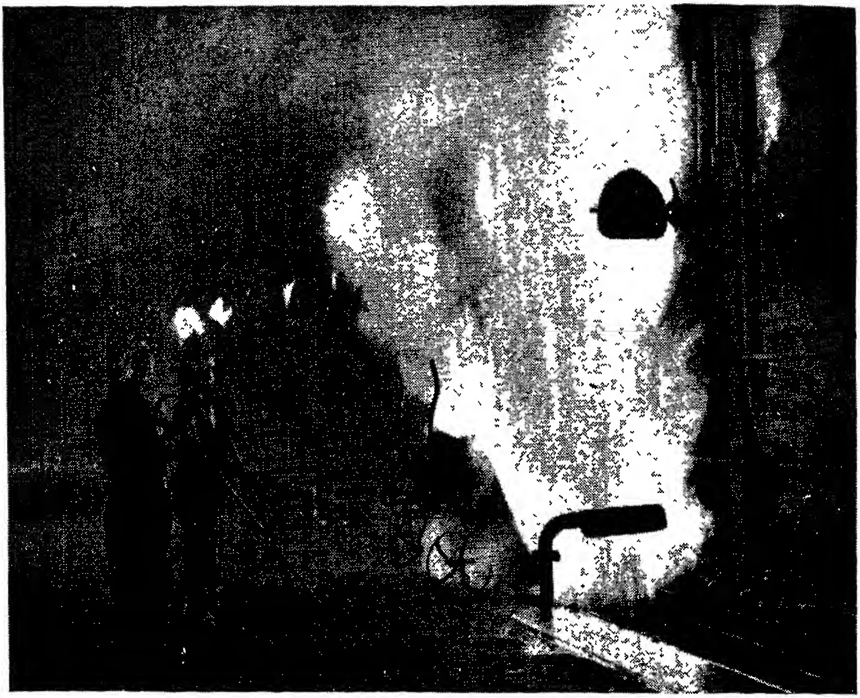
PROCESSES IN A MODERN GASWORKS:

FIG. 3. *From the above drawing may be followed in their usual sequence the processes which take place in a typical gasworks, from the reception of the vast quantities of coal, often brought by canal or river, to the gasholders from which domestic gas is distributed at even pressure into the mains.*



HOW BY-PRODUCTS ARE RECOVERED

Coal is heated in retorts forming gases and vapours that are volatile, and coke which is later discharged from the retort when the gases have been driven off. The gas is passed through the successive stages shown above to remove the many impurities and recover valuable by-products.



DISCHARGING HOT COKE

In a gasworks, women operatives watch hot coke being discharged from a retort in a horizontal retort house. To an accompaniment of flames and steam, the coke is quenched in water; and a charge of fresh coal is placed in the retort, where, in its turn, it is coked to produce our gas. Special drawings demonstrating how such retorts actually function are given in Figs. 4 and 5.

the gas engineer and manager of a large provincial gas undertaking. He explains that his undertaking has to cover three main activities: gas-making, the distribution of gas to consumers, and showroom and consumer-service work. He himself is in ultimate charge of all these activities.

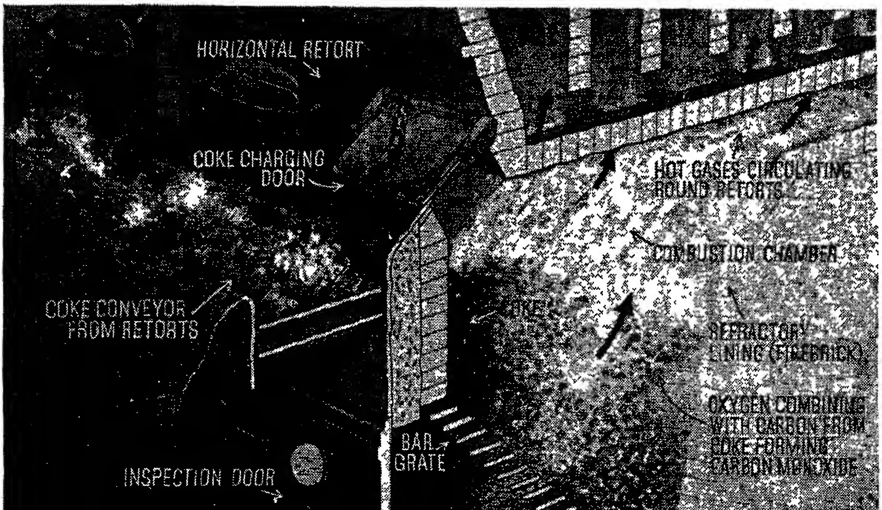
How retorts operate

Routine control of gas-making is in the hands of the assistant gas engineer, who explains that three types of retort are commonly used in gasworks: the horizontal, continuous vertical, and intermittent vertical. The horizontal and the continuous vertical retort are the more usual. We enter the horizontal-retort house, and find ourselves in a long corridor one side of which is formed by the battery of retorts. It appears as a brick wall about 10 ft. high festooned with semi-circular iron doors about 2 feet high and arranged in four rows one above the other. Each retort is a chamber with a flat floor and an arched roof, about 2 ft. wide, 20 in. high and 20 ft. long, with a door at each end. The retorts are built in "benches" four or, in some installations, five retorts high and two wide, and as many benches as are required are placed side by side to form the battery we see. Each bench of retorts is heated by producer gas generated from coke by a producer built into the base of the setting, and the gas from the coal charge in the retort is taken off by two

stand pipes leading off from the retort roof, one near each end door (Fig. 5).

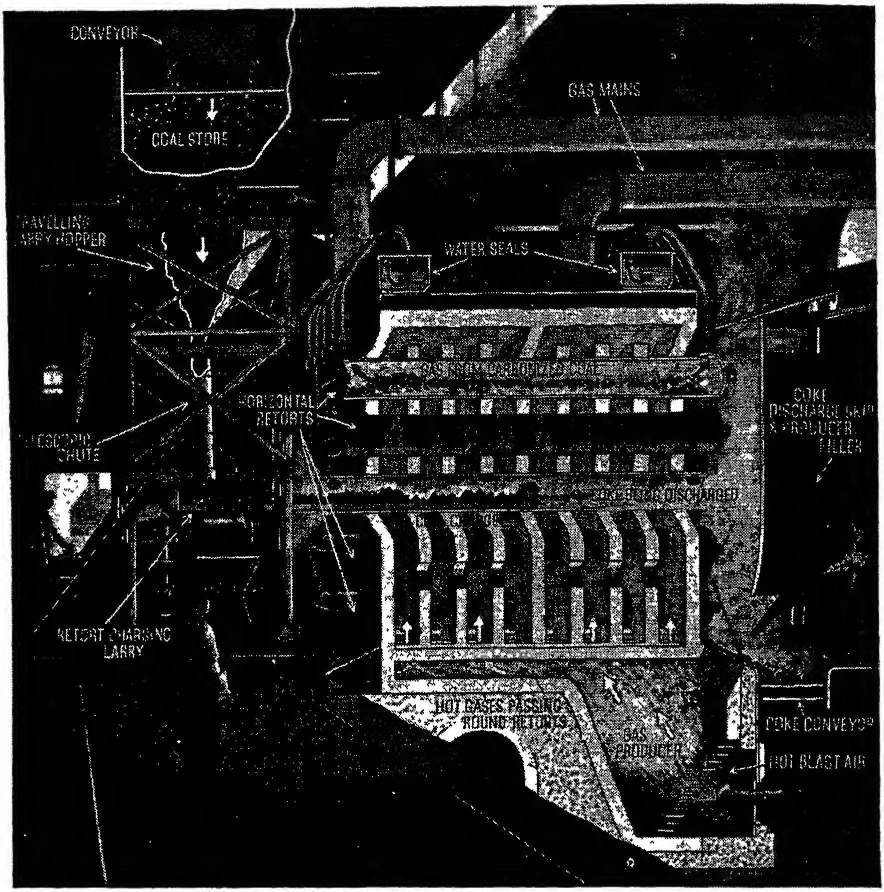
About the difference between coal gas and producer gas, our guide remarks that if coal is heated in a closed retort it distils off a high-quality gas, known as coal gas, along with a series of by-products, leaving behind the solid residue known as coke. But if this coke is now put into a producer, ignited, and given a restricted air supply, it will itself be converted into a much lower-quality gas known as producer gas—not good enough to feed into the public supply, but quite suitable for heating retorts.

Our attention is drawn to a large machine, mounted on rails and travelling slowly down the length of the battery. In it an operator is sitting, presiding over a group of electrical controllers. At each retort he opens the door, and after signalling to a doorman at the rear of the battery to open the rear door, he starts a motor which drives a steel ram into the retort, pushing out the hot coke before it. The coke falls on to a conveyor and is quenched by sprays of water. All the retorts in a horizontal row are dealt with in this manner, after which the charging machine and the rear doorman return to the far end of the row to charge the retorts. The rear doorman holds a shield a few inches inside the retort, and a fresh charge of coal is inserted mechanically from a hopper on the charging machine. When the bottom row of retorts is being discharged, the rear doorman opens a hopper leading to the producer, and the discharged coke falls straight into this hopper. On the top of the battery a man



HOW A HORIZONTAL RETORT IS HEATED

FIG. 4. *Producer gas (of a quality not suitable for domestic consumption) obtained from coke heats the batteries of horizontal retorts. The hot coke from the retorts is pushed out of each retort by a steel ram and falls on to a conveyor belt, the retort being then recharged with fresh coal. On the next page is given a full section of a horizontal retort, of which the above is the base.*



SECTION OF HORIZONTAL RETORT

FIG. 5. *This section of a horizontal-retort house shows in detail how the batteries of retorts are charged by a machine travelling on rails and controlled by electricity. As the fresh coal is rammed in the coke is simultaneously ejected at the other end of the retort.*

is occupied in cleaning the standpipes of each retort after it is discharged, and in the basement another man is attending to the producers.

The continuous vertical retorts are chambers about 10 in. wide, 4-9 ft. long and 25 ft. high, into which coal is continuously fed at the top and coke continuously discharged at the bottom. Very little labour is required to operate these retorts as they are virtually automatic. A man is stationed at the top of the retorts to regulate the charging magazines and see that the coal flows freely; a second man below the retorts drops the coke into a wagon and wheels it away; a third attends to the producers (Fig. 6). Intermittent vertical retorts are somewhat similar to continuous verticals; no machinery is required for charging or discharging—gravity does the work.

Whatever the type of plant, the assistant gas engineer has to determine the charging schedule and the temperatures

and pressures that must be held at various parts of the plant to obtain the best results. In this he is ably assisted by the shift foreman, an experienced practical man who sees that conditions are maintained as desired. He also receives valuable assistance from the works chemist, who watches conditions throughout the entire gasworks.

By-product plant

Our guide now takes us forward to the by-product plant. He explains that the gas as it leaves the retorts is a thick brown smoke such as we get at home when we put overmuch fresh coal on the fire—containing many substances which can be removed to form a valuable series of by-products. First the gas is passed through coolers in which tar is condensed. The liquid tar is shipped to a tar distillery where it is split up into a variety of chemicals forming the basis of a bewildering range of valuable commodities. Working in conjunction with the coolers are machines known as exhausters, which suck the gas out of the retorts and pump it through the by-product plant. After the tar condensers the gas is washed with water to remove ammonia, the resulting liquor being sent to a chemical works for preparation either as liquid ammonia or as sulphate of ammonia (Fig. 3).

The next stage is the removal of sulphur

FRESHLY LOADED RETORTS

After the retorts have been recharged, the coal is pushed back from the mouthpieces of the retorts and the doors closed. This process is known as "backing up." Above is seen a woman operative "backing up" one of the middle retorts, from the open mouth of which gush flame and smoke.

one of the most troublesome impurities. "Many people think that a gas fire dries the air in a room," declares our guide. "In fact, the burning of gas forms steam which *moistens the air*. The dryness in the throat that some people experience is due to old-fashioned stoves, etc., as we attach great importance to removing all the sulphur we possibly can." He then shows us a group of enormous boxes filled with iron oxide, which absorbs the sulphur. The oxide purifiers are the only part of the by-product plant requiring much attendance, and even this is only required periodically. There is a by-product attendant, in charge of the whole of the by-product plant, who watches the gas pressures in the oxide boxes, tests the gas for sulphur, and, as necessary, alters the rotation in which the boxes are used. When a box is completely exhausted it is opened, and a gang of men dig out the spent oxide and refill the box, the spent oxide, now containing nearly half its own weight of sulphur, being sent to a sulphuric-acid works. We now pass on to the naphthalene scrubber, where naphthalene—the substance of which moth balls are made—is removed, and thence to the benzole recovery plant, the crude benzole being sent away to a benzole refinery.

"Not *gasometers, please!*"

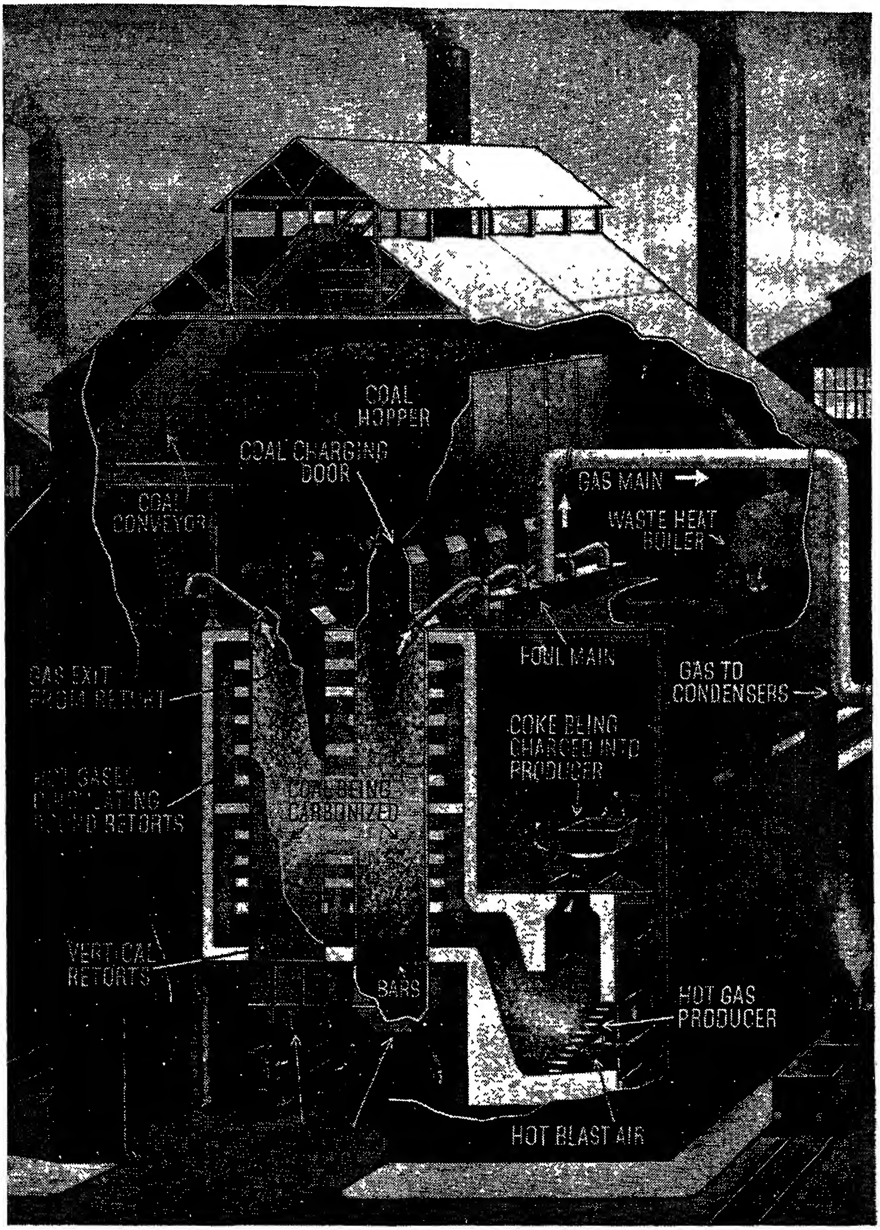
The gas is now clean, and after being cooled and dried is passed through the station meter in the valve house, where a valve-man controls the delivery of the gas to the gasholders ("*Not* gasometers, please!" our guide insists) and to the mains. In the valve house is an important item of equipment known as the gas governor, regulating the gas pressure in the public mains. If the gasworks is interconnected with other works, the valve-man also controls the connecting mains and is in charge of the boosters—boosters being machines that pump the gas through these mains.

A gasworks supplies not only gas but also a valuable commodity known as coke. We see the coke-grading plant, where the coke is passed through screens—mechanical sieves—to sort it into various sizes. The various sizes fall into separate bunkers, from the bottom of which they are carefully sorted into sacks.

From works to consumer

Our next task is to follow the gas on its journey from the works to the consumer. For this purpose we must needs return to the head office to meet the distribution superintendent, who explains that he has to watch the demand for gas throughout the supply area, assess probable future demands, and decide the size and location of mains to carry the required supply. This applies more particularly to extensions, but it may be necessary on occasion to enlarge or duplicate an existing main that has become inadequate. It is part of his duty to see that the distribution system is maintained in good order. He has men going the round to empty water from syphon pots and check gas pressures, and he keeps mobile gangs for repairing mains, laying extensions, and putting in service mains for new consumers.

Consumer service is a cardinal policy of the gas industry. Specially trained fitters are maintained to inspect and adjust consumers' appliances, make repairs, and install new appliances. Although the domestic market is vitally important, a tremendous amount of gas is used commercially and industrially. Much work in this direction has been done by the British Commercial Gas Association, and a number of the larger cities have Industrial Gas Centres. A staff of industrial gas engineers is maintained to advise factory managements on the installation and operation of gas appliances. Our guide also mentions the gas showrooms and the very important work of the appliance makers.



VERTICAL RETORTS IN SECTION

FIG. 6. *As is shown above, the continuous vertical retort requires little labour, being virtually automatic. A man stationed at the top regulates the charging of coal, which is eventually discharged as coke into waiting wagons at the bottom. The retort is about 25 ft. high. Other men superintend the charging of coke into producer-gas apparatus which heats the retort.*

SPIRIT OF BRITISH AGRICULTURE

Powerfully steering over the stubble, this farm tractor and its alert-looking driver are symbolic of the new spirit of British agriculture which, whilst preserving the best of traditional principles of husbandry, has introduced scientific research and management and modern, labour-saving machinery into the production of food to feed our people.

BACK TO THE LAND
MODERN FARM METHODS

By "AGRICOLA"

Britain's farming policy. Increasing soil fertility and the yield of the land. How the modern farm is planned to ensure a balanced production. Crop rotation and care of the soil. Carrying out sowing and harvesting. The art and purpose of ploughing by tractor and horse. Prevention against insect pests and diseases.

Of all Britain's industries none is more vital to her very existence than agriculture. To the townsman, it has been all too easy to view "the country" as a beautiful effect. Age-old farmsteads, grey churches warmed by the sunshine; a pattern of furrows on a down-side; wind ruffling the tree tops and waving the corn: in art and romance such things have a valuable place, but the farmer (with his own sense of values) knows the meaning of the pattern and judges the signs. He is the technician on the spot, the man who is *using* the land.

The Second World War brought a pledge to British farming and one unique in its history. In November, 1940, the Minister of Agriculture announced that the Government had decided to guarantee that the existing system of fixed prices, and an assured market, should be maintained during the period of hostilities and for at least one year thereafter. The Government declared further that it recognized the importance of maintaining after the war a healthy, well-balanced agriculture as an essential and permanent feature of national policy.

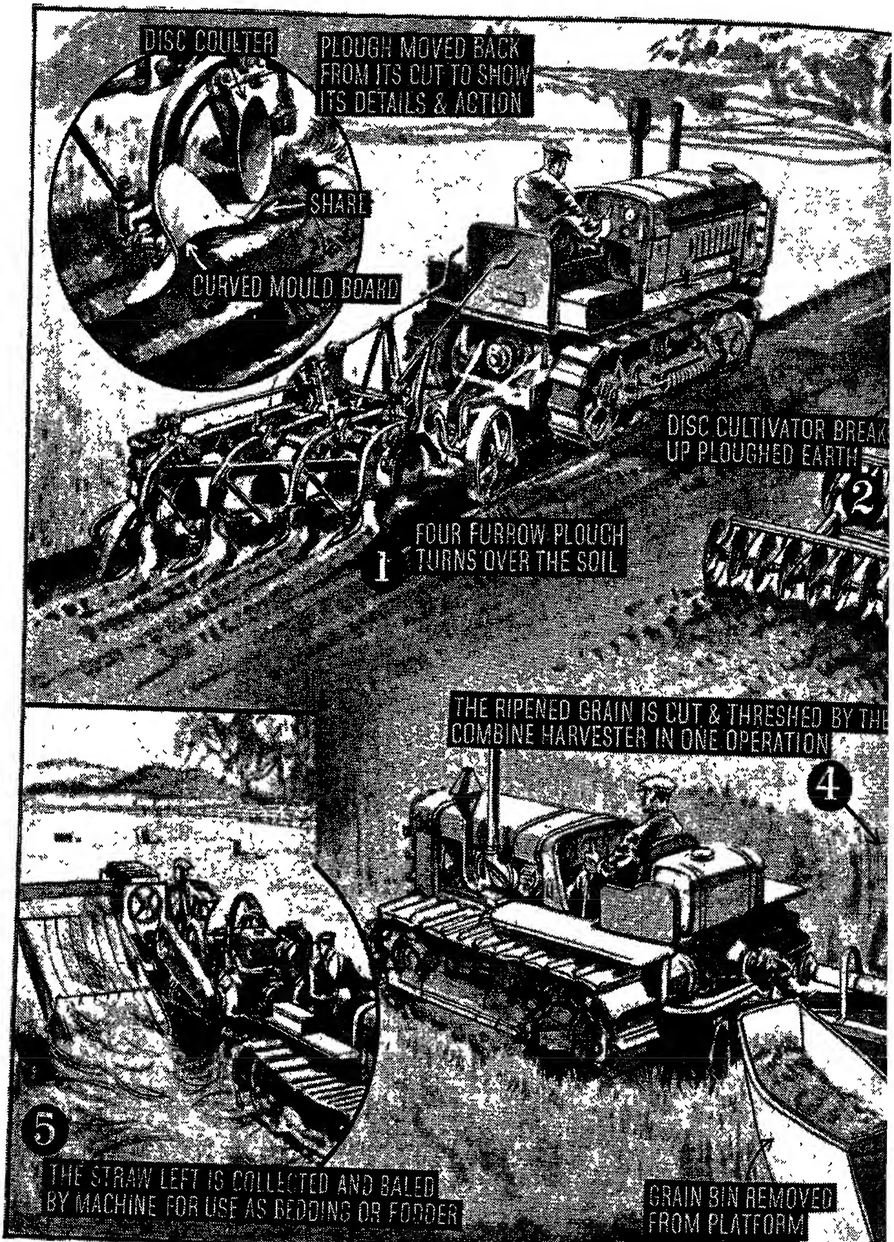
It is important to stress how vital it is to maintain the labour force in the industry. Apart from the national minimum wage for agricultural workers—in itself an enormously important matter involving considerations which must be passed over here—any permanent policy designed to effect and maintain a prosperous countryside must make adequate provision for housing requirements and rentals placed upon an economic basis.

The National Farmers' Union has decided what it considers to be the minimum figures, under "mixed farming," which will maintain soil fertility and produce an economic output from our soil in peace-time. Their figures (obviously subject to revision) are: *Tillage acreage* (excluding all leys) 11,000,000 acres, including 2,250,000 acres under wheat; potatoes, 600,000 acres; sugar-beet, 400,000 acres; fruit and vegetables, 800,000 acres. *Livestock:* dairy cattle, 3,500,000; other cattle, 4,000,000; sheep, 20,000,000; pigs, 3,750,000; poultry (holdings), 60,000,000.

Beef and milk requirements

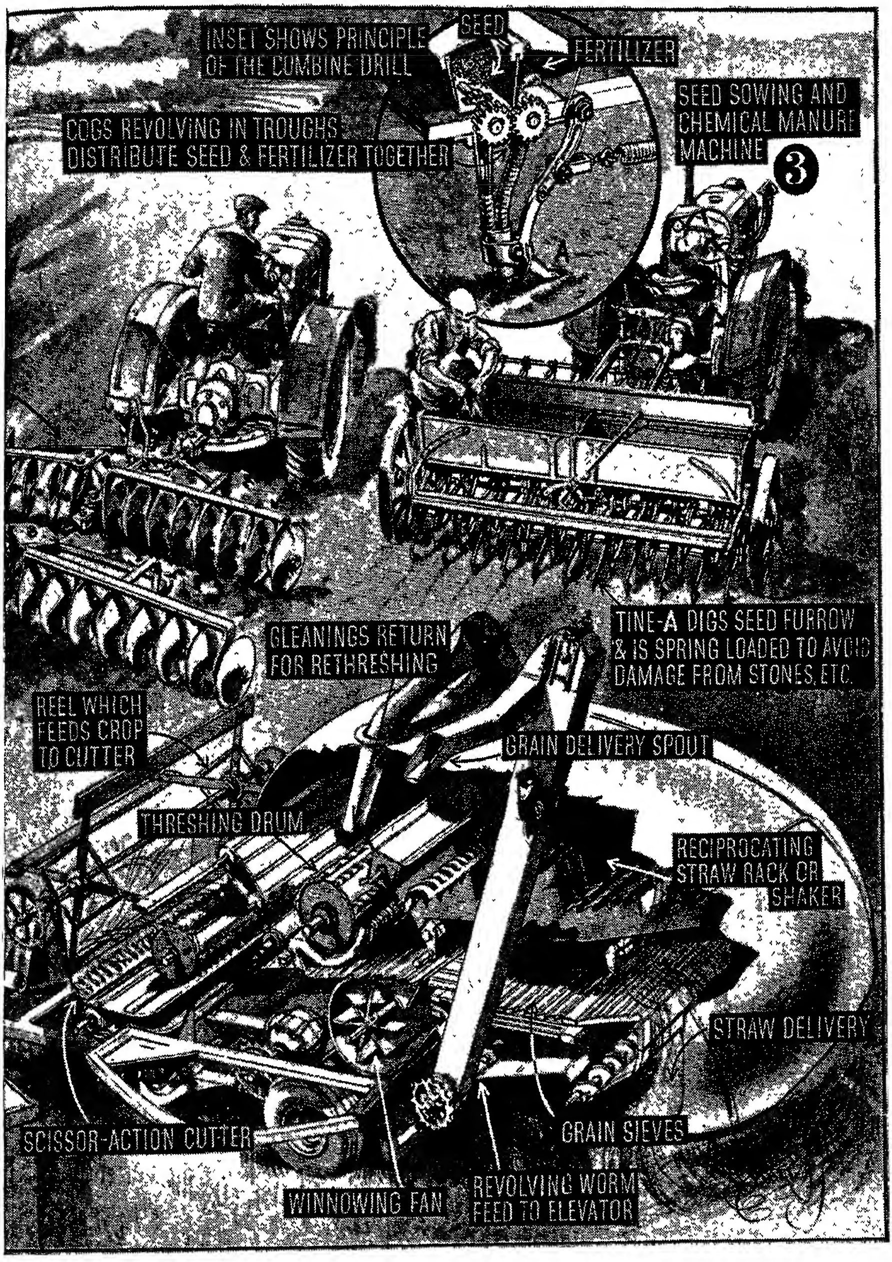
From the 3,500,000 dairy cows which will eventually be kept in this country, something like 1,750,000 bull calves will be produced annually and from them must come a large part of our beef supply.

Britain has an ideal breed in the dairy shorthorn to meet these post-war requirements. It produces good quality milk on home-grown produce at as low a cost per gallon as any other breed. It lends itself to the system of out-wintering, or wintering in open straw yards.



HOW INDUSTRY HAS HELPED

FIG. 1. *Mechanization has been the keynote of farming development for the past twenty years, tractor-driven machines like those shown above displacing time-honoured methods of cultivation and resulting in an immense saving of time and labour for modern farmers and the whole nation.*



THE MODERN FARMER

The four-furrow plough will turn over a field for next year's crop in a fraction of the time taken by the horse-drawn plough. Combine drills distribute fertilizer and scatter new seed in one operation; while the ingenious combine harvester speedily cuts and threshes the ripened crop.

Though small in size, Britain possesses an unexampled range of soil and climate and for this reason our farming is the most varied in the world. Corn production, and stock rearing, market gardening and dairying, large-scale mechanization and small holdings, flourish side by side. Agricultural machinery, shown in Figs. 1 and 2, has made Britain capable of producing a very high yield and has made it necessary for the farm worker to add a knowledge of machinery to his traditional skill.

The farm to-day is planned to ensure alternate husbandry and its result will be to increase rather than diminish the arable acreage and to place still more reliance upon mixed systems (Fig. 4).

Crop rotations must be observed more than ever. There are so many rotation variants that it is impossible to place them all on record. For instance, the rotation which produced the 1943 champion crop of British barley was a two-course rotation of barley, sugar-beet and barley once more. This crop was grown on fields at Bridgnorth, Shropshire, sloping fairly steeply to the west. The seed was sown in March and no fertilizers were used, only the goodness that was left in the soil by the previous crop of sugar-beet. To maintain fertility on this light land—miles away from the sea coast—a flock of 120 ewes and their followers were kept.

If one quotes an example of a typical rotation, a clear idea of what it means, and how it lends itself to the present system of corn and root culture and keeping the land clear, is obtained.

At all times, in peace or in war, the British farmer has been compelled to

RECORD CORN CROP

To produce the food needed by Britain's millions, a greatly increased acreage has come under the ploughing-up policy. The two young men shown in the above photograph are cutting part of a record corn crop on one of Britain's largest farms.

COMBINE HARVESTER

Sailing over the undulating farmland with something of the grace of a ship, this great combine harvester, which gathers, threshes and delivers the ripened grain in sacks in one comprehensive operation, is seen with its crew after an afternoon's harvesting.

practice various rotations of crops to suit the special circumstances of differing districts; even of differing farms.

Wheat, generally, is grown in rotation with other crops, although there are some notable instances where this crop has been grown on the same land year after year for research and demonstration.

Cleaning the land

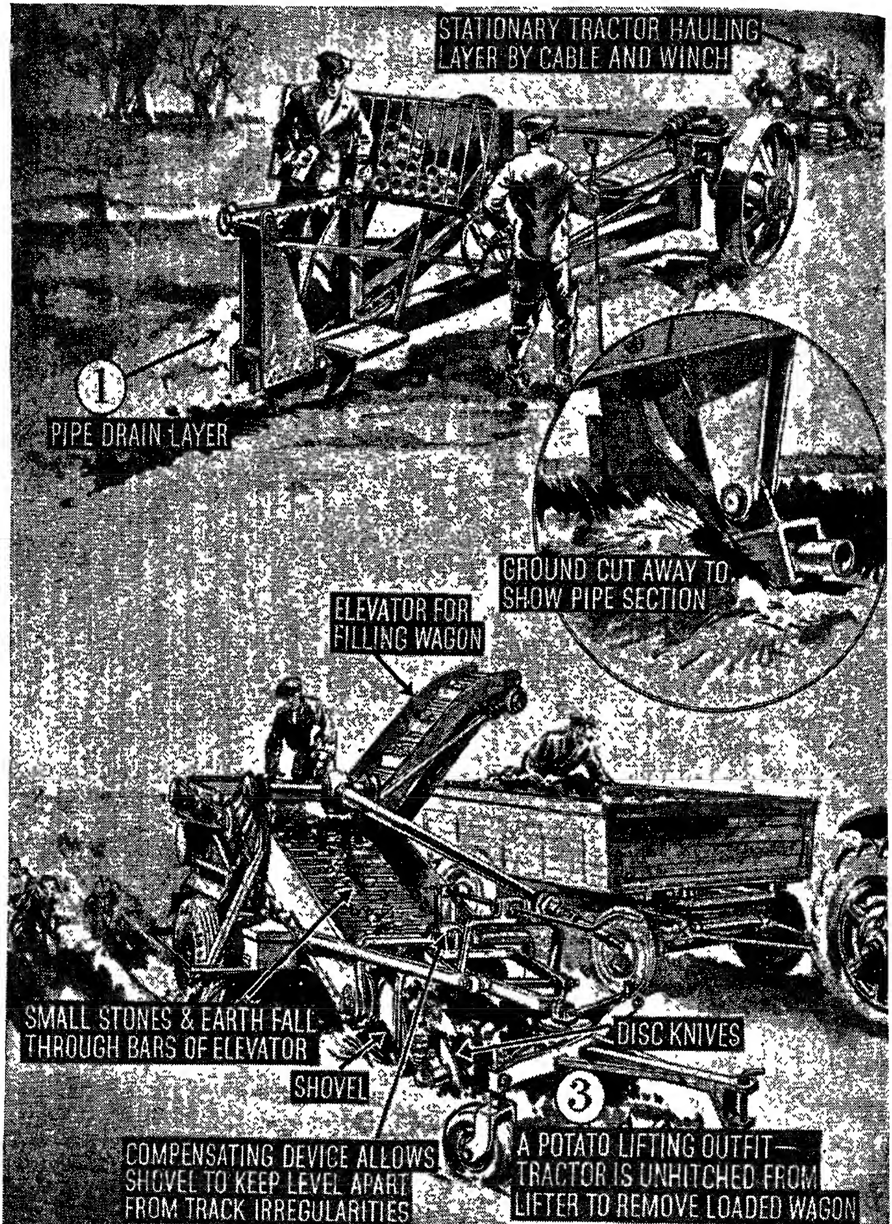
Taking the Norfolk, or four-course rotation, as our example, it commences with a root crop, usually swede turnips, manured with phosphates, and, where the land is light, potash. This crop cleans the land and gives food for sheep and cattle.

Part of the roots are left on the land and are eaten by sheep during the winter. These roots, however, are neither satisfactory nor suitable as a complete diet for sheep; they must be supplemented by hay or a concentrated food, rich in nitrogen. In peace-time, it is usually linseed cake.

Sheep retain only one-tenth of the nitrogen provided them and thus nine-tenths of the nitrogen of the roots, hay and cake consumed, go back into the land. Furthermore, the treading of the soil, in a wet condition, provides a firm seed bed for the following crop (Fig. 3).

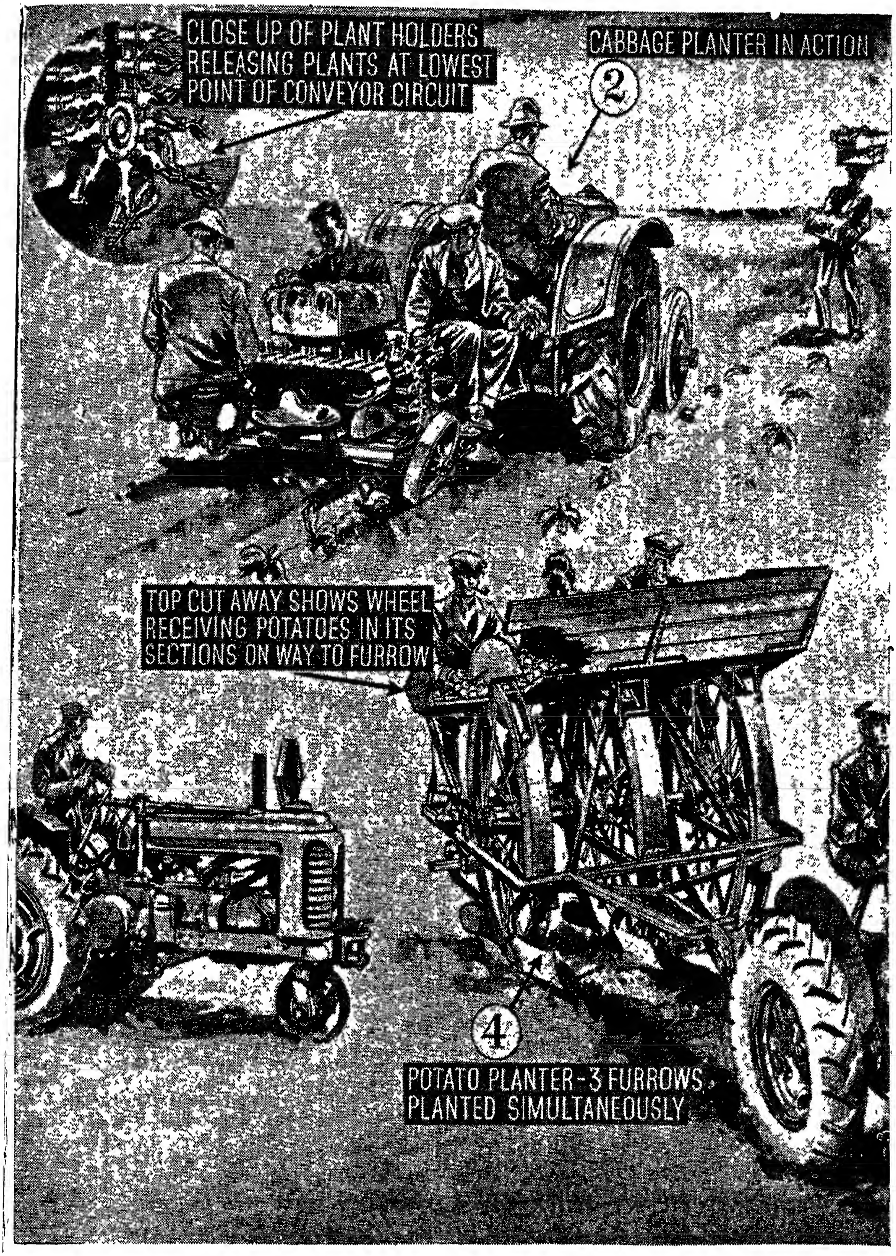
The rest of the roots, grown in this first case, are gradually fed to the cattle being fattened for beef. Here also are the roots supplemented by hay, straw and cake. Straw from a former crop is utilized as litter. It soaks up the excreta of the feeding cattle and this valuable farmyard manure is kept for future use.

When the sheep have consumed their portion of the turnip crop, they are



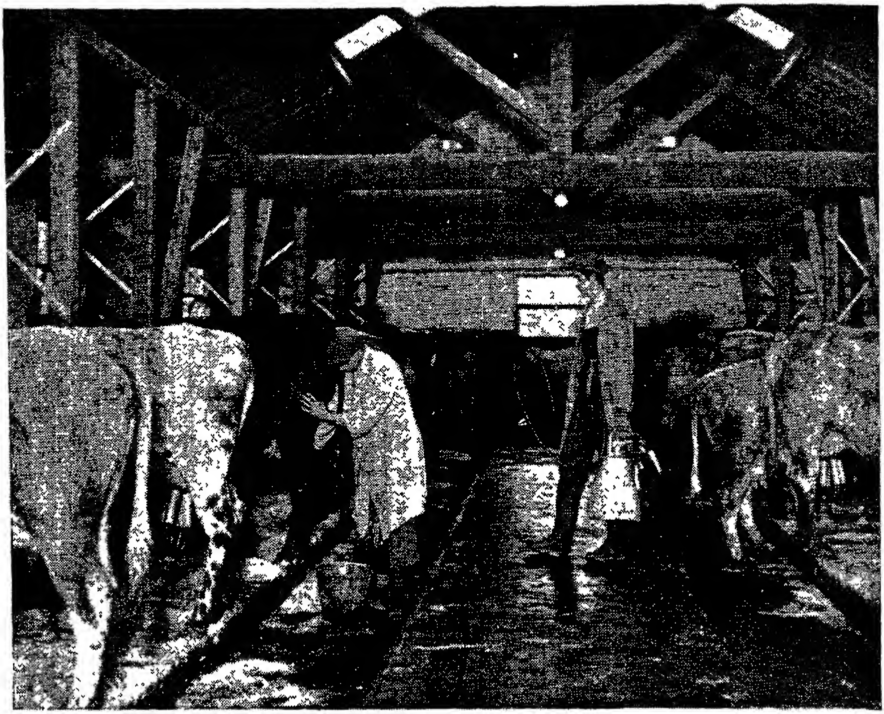
AIDS TO AGRICULTURE

FIG. 2. *Illustrated above is a further selection of the mechanical devices used in large-scale farming. The laying of drainage pipes and lifting of potatoes are two tasks which have previously taken a considerable expenditure of time and energy, but now with the use of appropriate machinery can be accomplished as effectively and far more quickly than manual labour could achieve.*



AND HOW THEY WORK

Not only the cropping, but the planting of vegetables can be facilitated by the use of machinery. Shown above is the working of the cabbage planter, which sets the young plants with automatically correct spacing, and the potato planter, capable of setting three furrows of seed simultaneously. With the wholesale adoption of such ingenious devices as these began a new agricultural era.



MILKING BY MACHINE

Cleanliness is the keynote of milk production and modern dairy equipment is designed to avoid possible milk contamination. Above is seen a power-driven mechanical milker in operation. Working on the suction principle it milks several cows at once, the milk being drawn off through tubes.

disposed of as mutton. The land is then ploughed—not too deeply—and the surface soil is pulverized by harrowing until a smooth seed bed is obtained and barley is sown early in spring.

Clover and grass seeds are sown among the barley in order that they may secure a firm root whilst the barley grows and ripens. In autumn the barley is harvested. The clover and grasses develop during the autumn and winter and the result is a hay crop the following summer.

Towards the end of June the men harvest it and its aftermath makes reliable autumn grazing for sheep and cattle which have to be fed during next winter.

Farmyard manure, produced during the period of cattle feeding in the previous winter, is next loaded up and carted on to the clover land. With the approach of a rainy spell it is ploughed in and a seed bed for wheat is prepared.

This wheat should be sown as soon as possible after the end of September so that the young plant may establish itself in a soil still reasonably warm and before winter frosts set in.

Harvesting usually takes place in August. The wheat stubble should be ploughed in the autumn and again in the spring, and when the time comes to sow the roots the land has been "cleaned" to a great extent.

That is the story of the complete four-course rotation, with all the advantages it brings to the soil, farm stock and crops. By this system also the farm workers distribute their labour over the year.

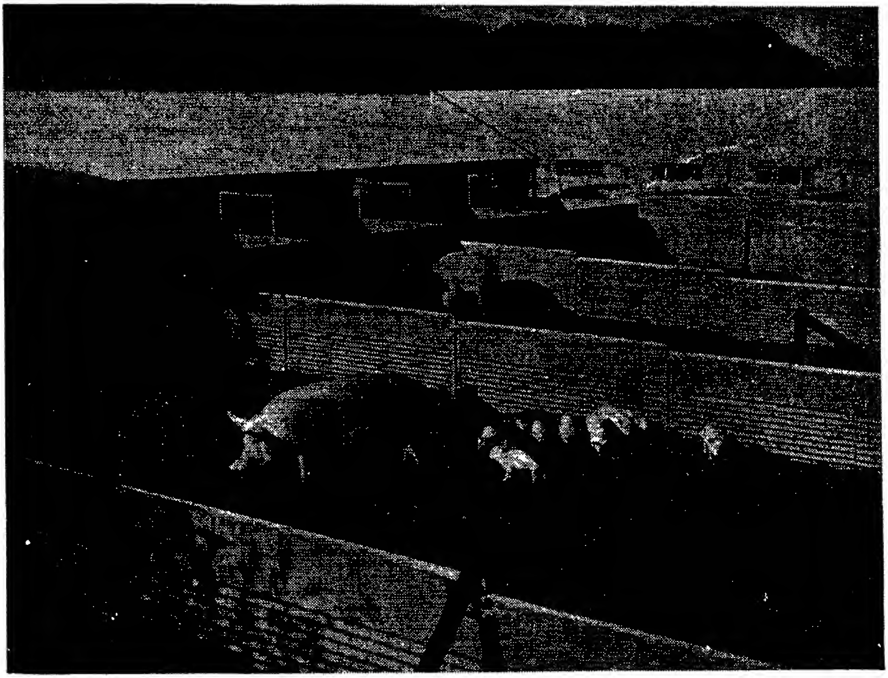
Each crop comes on to the same field only once in four years. This rotation makes appeal in areas where rainfall is deficient. Advice as to other essential fertilizers to be used should be obtained from the county agricultural executive officer who has full information.

How the plough is used

Ploughing is the principal act of cultivation in preparation for any crop. Ploughs are made for a variety of purposes, but essentially the plough consists of a stout beam which makes a curve at the rear, the point of which forces its way through the ground, and a side sheet of metal called the "mould board" which turns aside and inverts the loosened soil. The beam is continued behind the curve so as to form a steering or guiding handle, and wheels are often attached to the fore-part to make the running steady and to regulate the size and depth of the furrow.

Considerable skill is called for in the ploughman's craft. It is not only necessary to plough a straight furrow; the ploughman must be able, by adjusting the pressure on the handles, to deal with the variations in soil heaviness, which occur in every field. In fact the art of holding the plough is a nice question of balance, the pivot being those parts of the body and breast of the plough in contact with the ground.

These remarks apply to a horse-drawn, man-handled plough. In the case of tractor ploughing the setting is rendered constant by the fixing of the plough to the

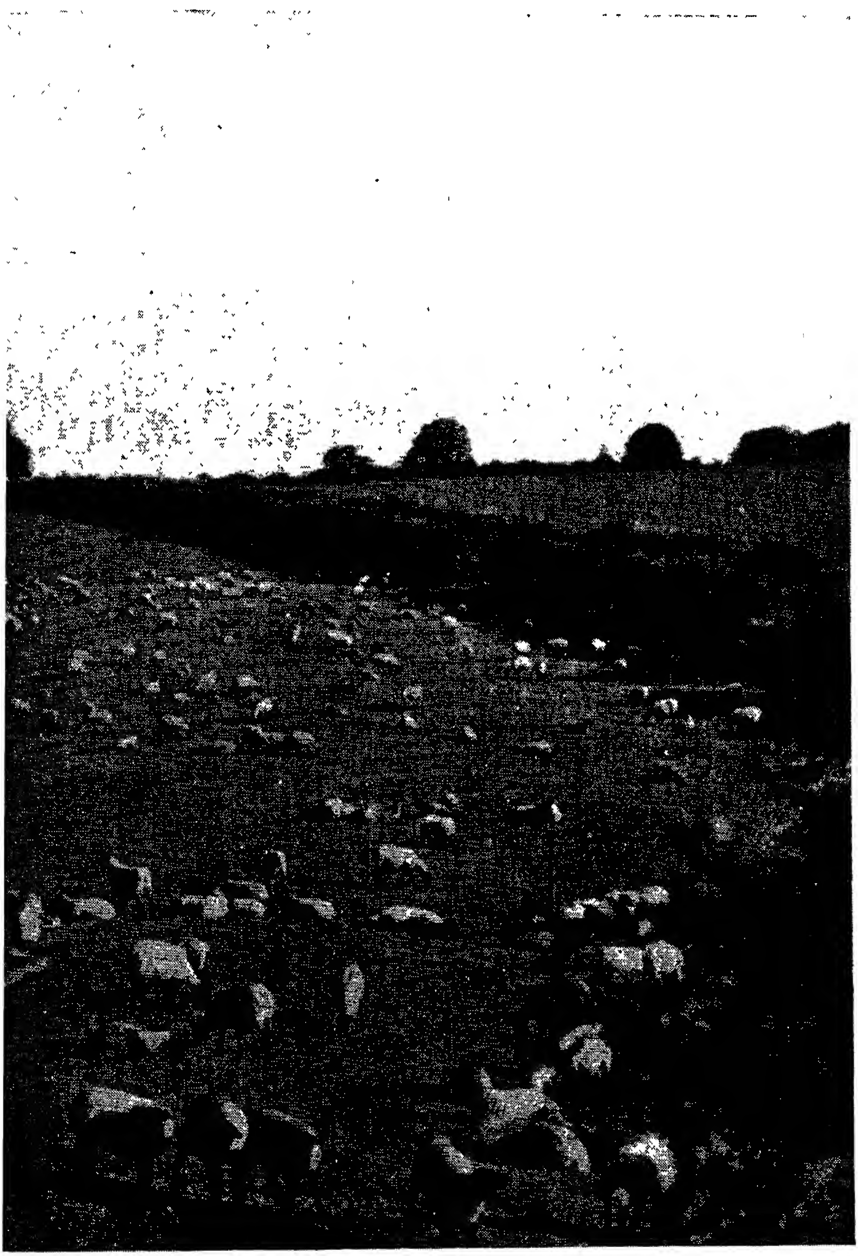


MODERN PIG-KEEPING

Pigs have the undeserved reputation of loving dirty surroundings, but actually they thrive best when kept in clean, well-tended styes on the Danish principle, an example of which can be seen above. A sow is rooting in the foreground, surrounded by her latest litter, of which she produces two a year.

SHEEP HELP PREPARE FOR

FIG. 3. *First-class crops can only be produced when the fertility of the soil is renewed by the rotation of crops and adequate manuring. Sheep have been turned out on to this typical Norfolk pasturage, and the soil is now ready to be broken by the plough and sown for next year's corn crop. Fertilization of the soil by this natural means is not only economical but highly productive.*



A BUMPER CORN HARVEST

Cattle will not graze on land on to which sheep have been previously turned out, although sheep are able to maintain themselves on the grass left behind by cattle. The flock in the above photograph are cross-bred Suffolks—a valuable utility type that provides mutton as well as wool. One of the characteristics of this popular breed of sheep is their black faces and black legs.

HARVEST VOLUNTEERS

Harvesting is a time when the farmer and his men are busy from early morning to dusk gathering in the crop while the fine weather lasts. It is also an opportunity for city workers on holiday and school children to lend a hand at the unskilled work, as is shown by the typical scene reproduced above.

tractor. But there is a danger here. The old-time ploughman could tell whether the resistance factors involved in the setting of the plough were properly proportioned to the job in hand.

With a powerful modern tractor there is a risk (in default of the capable hands of the ploughman) of a maladjustment passing unnoticed. A wrongly adjusted plough takes more effort to pull than it should with a consequent wastage of fuel and mechanical effort.

Some striking calculations of the waste of effort and fuel by wrong plough-setting have been made. One eminent firm of plough-manufacturers even estimated that so apparently small a thing as a rusty mould-board will require 18½ per cent. of extra effort and use up two additional gallons of fuel in an eight-hour day.

Hallmarks of good ploughing

The functions of the plough are: To turn over the soil exposing it to the action of the elements (every gardener knows how important is the action of frost, sunshine, etc., after digging); to bury the stubble, weeds and other vegetation; and to provide a rudimentary drainage system for excess rainfall.

Points to look for in good ploughing are therefore: Furrows straight from end

to end; uniform depth of ploughing; complete burial of all weeds and other vegetation, and all dung if present; uniformity without breaks or depressions of the tops of the furrows.

All common field crops are subject to attacks from insect pests. No fewer than five pests of this kind will, if permitted, attack barley; wheat is subject to three such visitants; oats to three; beans to two; cabbage and rape to five; peas to three; potatoes to two; mangolds and sugar-beet to three.

Great Britain has twenty-four distinct breeds of cattle—milk, beef, and dual purpose. In numbers, the Shorthorn, through its dairy type, is the strongest breed in the country. Ranking next is that voluminous milker the British Friesian, a breed built up of Dutch and South African importations of the Friesian.

Gradually forging ahead out of its native East Anglia is the Red Poll, a genuine dual-purpose milk and beef breed whose offspring can win prizes at both fat stock shows and dairy shows on the merit of their beef carcases and their real butter-fat milk.

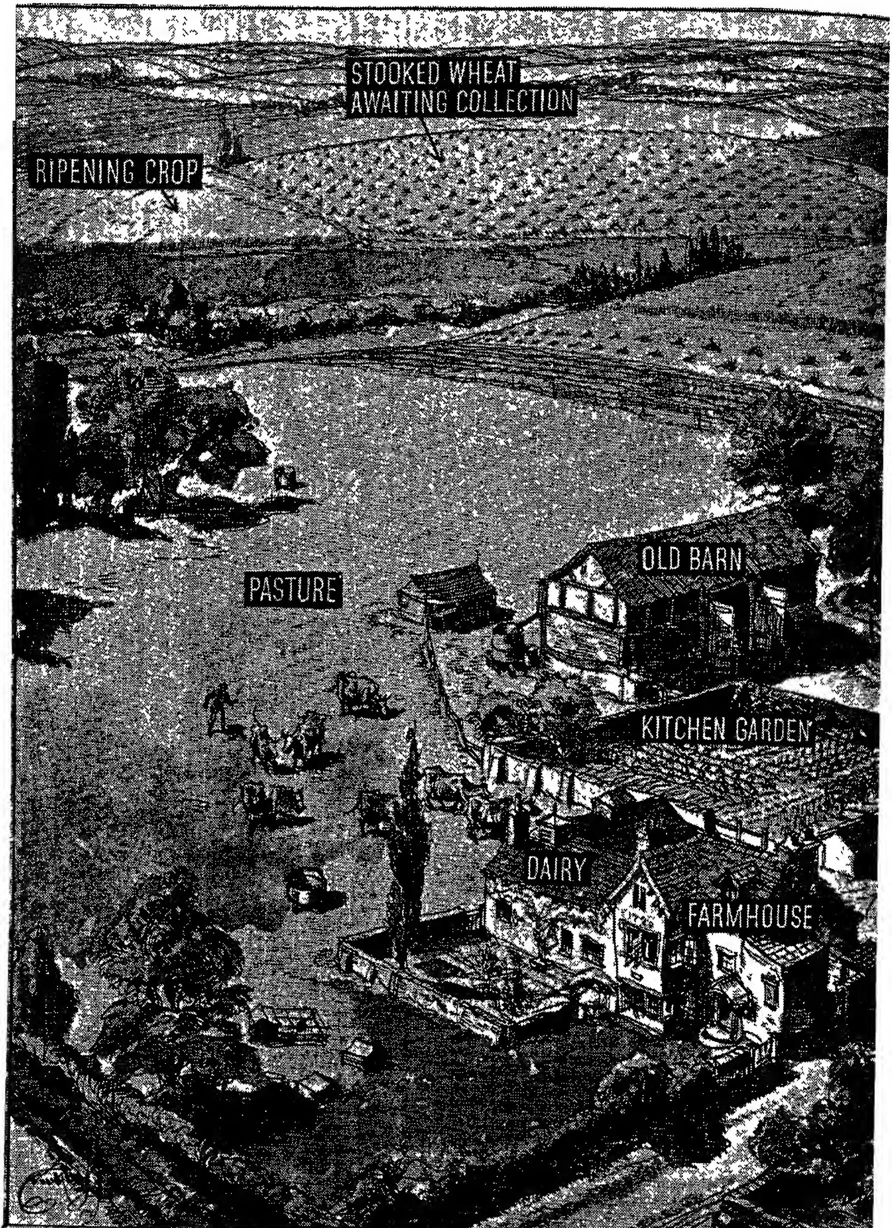
Britain's wonderful cattle breeds

The white-faced Hereford, which has made friends because of its proved beef qualities in many new countries overseas, still provides the prime beef in the Midlands and west Midlands of England, where soil and weather conditions suit the breed.

Devon has two breeds—the deep red-skinned beef cattle of the northern end of the shire and the heavy yielding butter-fat

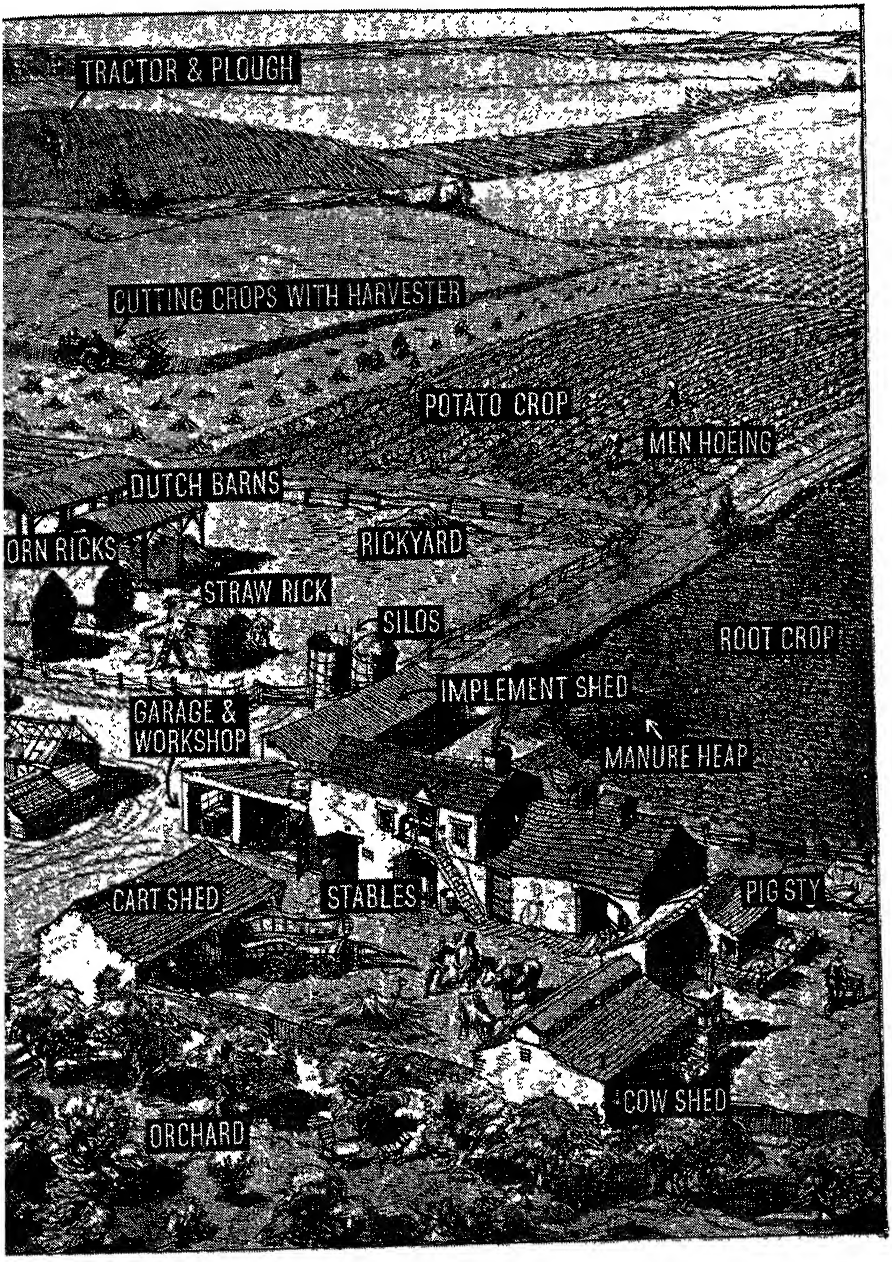
LIFTING SUGAR-BEET

Sugar-beet has become one of the most valuable crops to the farmer. Above is shown the beet being lifted from the soil in autumn by means of a beet lifter, which is adjusted to work at any required depth. Other ingenious machines exist to top the roots either before or after lifting.



HOW A TYPICAL BRITISH

FIG. 4. *Although the layout and size of a British farm varies considerably according to the district and type of farming suitable to it, the above drawing gives an impression of the layout of a medium-sized farm. From it may be seen the amount of work that is necessary during the summer months, when the farmer and his farmhands must be "on the job" from the crack of dawn until nightfall.*



FARM IS PLANNED

Well-balanced use of the land is shown in the scene above. The wheat crop is in process of being gathered in by a tractor-drawn combine harvester; while roots and potatoes are cleaning the land to the right of the drawing, and also providing valuable winter fodder for the cattle and pigs, furnishing an important addition to the produce of the farm and manure for use on the fields.

producing South Devon, found in great numbers in that part of the county.

Sussex (beef), Wales (beef and milk), Aberdeen-Angus (beef), Galloway (beef), Ayrshire (milk), the Highlands (beef), and Lincolnshire (dual purpose)—each has its local breeds, proved through the years to suit their own immediate areas; but the Ayrshire, because of its heavy milking yields, has pushed its way not only over the lowlands of Scotland but even into Sussex, Berkshire, Kent and Essex.

Increasing in numbers in the west of England, the south-west and the Home Counties, is the Guernsey; and retaining an affectionate hold upon farmers in many parts of the country are the Longhorn, Belted Galloway and the Blue Albion. The last-named, like the Lincolnshire, is of Shorthorn type, having a blue-roan coat, whereas the native cattle of Lincoln are a self-red and primarily very heavy milkers. They will also feed up into an excellent carcase of beef.

Wool and mutton

There are no fewer than thirty-five breeds of long and short woolled sheep in Britain, for hill, downland or lowland pastures. Their names indicate their suitability for their localities, but some of them have travelled very far from their place of origin. The Suffolk and Oxford Down, for instance, have gone to Scotland; the Oxford Down, Hampshire Down, South Down, Shropshire Cotswold and the two Dorset breeds have been exported in considerable numbers to overseas countries engaged in building up their sheep stocks, along with the larger breeds, Romney Marsh, Lincoln and Leicester.

Wales has five varieties of sheep within her borders; Devon has four, including the Dartmoor; and there are other breeds peculiar to Cumberland, Lancashire, Wensleydale and elsewhere. Scotland's sheep breeds run to about a dozen.

Britain's pigs have fifteen different varieties and for commercial purposes, for early pork and streaky bacon, the changes can be rung a hundred ways. Most popular as pure breeds are the Large White, the Berkshire, Essex and Wessex. Wales and Ulster have their own breeds; so too have Cumberland and Gloucester, and in Tamworth there is one of England's oldest and best pigs.

Of farm-working horses, the Shire Clydesdale, Suffolk and Percheron fill the farmer's bill as the ideal farm-working horse and the foundation of the trade in street-working geldings. There are fifteen breeds of light horses and ponies, many thousands of which are bred annually on farm holdings and some of which play a part in the labour of the farm until they are sold at auction or to private buyers.

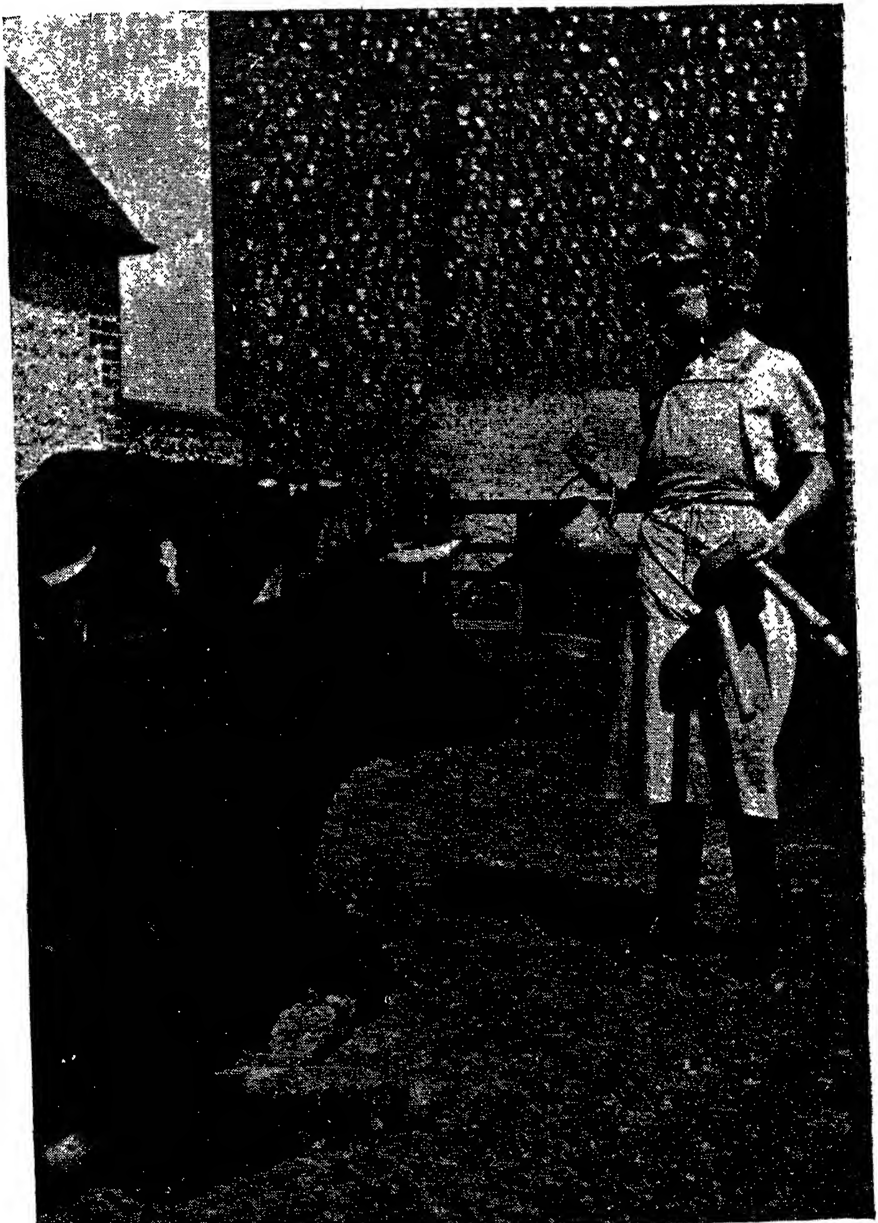
Men who work the soil

Enough has been said of the broad principles of farming to show the immense changes which have come about during the past fifty years. These include a new conception of the duties of the farmer and of farm workers.

The modern farmer, be he master or bailiff of a group of farms, or of a smallholding run with the help of his son, has become a highly scientific technician, relying on scientific principles.

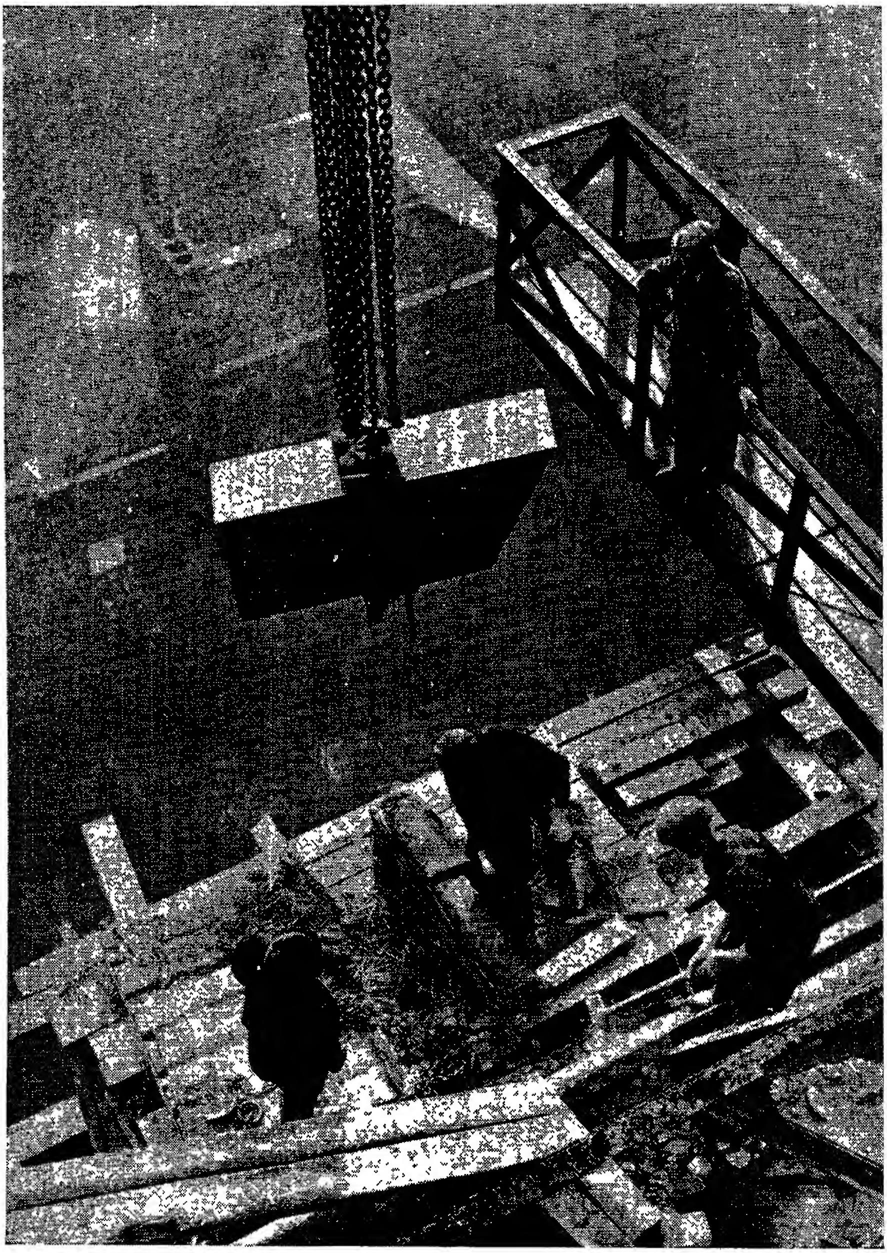
As to the farm workers, increased educational opportunities plus the advent of the machine into the world of agriculture have changed the stolid, inarticulate ploughman, shepherd, or teamster of thirty years ago from a type to an exception. Farm workers of to-day are conscious of their craftsmanship and have won much better conditions.

But for all this change, the man who works the soil has retained his belief in its virtues. As season succeeds season and he sees the timeless working of nature he can but achieve a calm and sober faith.



HAND-MILKING

With her pail and traditional three-legged stool the milkmaid is up at the crack of dawn to begin her duties. Hand-milking has been largely displaced by mechanical milking devices which perform the task in half the time, but on some smaller farms with only a few cows, where the necessary equipment has not been installed, the older method is still employed.



LOWER AWAY!

Advances are being made in speed of construction and this has been helped by the use of large stones in place of small ones. Mechanical devices now place these correctly and obtain the same result in one operation which formerly took much time and labour. The photograph reproduced above shows how a large stone slab is lowered by overhead crane down to the waiting workmen.

BUILDING PROGRESS ORGANIZATION THE KEYNOTE

By Alfred C. Bossom, F.R.I.B.A., M.P.

Wide range of new media. Concretes, pressed metal and plastics. Steel frame construction and hollow-tile usage. How concrete comes ready-mixed to the job. New and old methods of piping. Advantages gained from assembling prefabricated units on the spot. How time and progress schedules make for orderly working.

British building to-day is the result of developments all down the ages and, as the various changes have taken place, we can trace the prototypes of the homes, offices and factories in which we live and work.

The investigator is first impressed by the wide range of new media, especially the many forms of concrete, toughened glasses and plastics. Concrete, usually consisting of Portland cement, sand, gravel or broken brick and stone, nowadays forms not only the basis of our foundations, but, when cast in slabs, erected in blocks or poured between wooden shuttering or metal moulds, is often used for floors, walls, partitions, roofs and even for fire-proofing. Floor slabs are sometimes made out of cinder concrete of which coke breeze or ashes forms the aggregate. This was possibly the beginning of the new range of concretes alluded to as being mixed with "light aggregates." The light aggregates include pieces of burnt clay mixed with sand and cement, or a metallic foam produced from molten metal upon which water is suddenly dowsed, causing it to expand greatly. Then there are the aerated concretes in which bubbles of air are formed to make it light and sound-proof; the particularly heavy concretes, solidified by being spun or vibrated violently to exclude all air and water; and other concretes with special aggregates for wall treatments which can be hammered or chiselled to look like a sort of stone.

The different types of glasses used for windows and those applied to walls to protect the plaster from splashes, are gradually being replaced by new materials known as plastics, some of which are transparent and can be either light, heavy, fire-proof or inflammable: in fact, an entirely new range of substances whose possibilities are only just being investigated. Given consistent progress, it may be expected that such extensive developments will take place in the plastic industry as will enable us to have, if not houses themselves built entirely of such materials, at least interiors fashioned largely from them.

Modern construction

One of the main modern elements of construction is the fire-proof terracotta block or hollow tile (Fig. 4).

Where partitions were built of wooden studs, lath and plaster, they are often now made of these tile blocks with a layer of plaster applied on either side. Such partitions are fire-proof and it is not uncommon for a fire to burn itself out in one room so constructed without spreading. The same applies to floor and wall construction. Terracotta blocks can be lodged in between the steel beams and so

form the structural part of the floor, while walls built with brick or stone exterior layers are often lined with terracotta blocks. This forms a weather- and fire-proof construction and is, at the same time, much lighter in weight.

Almost without exception outer walls were in the past of heavy brick or stone construction, when not of timber or wattle-and-daub. Latterly, however, a frame of steel has steadily grown and advanced in popularity. This is made of beams rolled out in all sorts of sections—H, L, T—to which plates are either riveted or bolted. Where steel columns or stanchions are used, they are frequently protected against the risk of damage by fire by being enclosed in a layer of two, three or four inch terracotta blocks as has been described above.

Electricity's part

This brief survey of newer elements which have so revolutionized building methods during the last few years cannot be left without touching on electricity which has, in turn, introduced to the home new forms of heating, lighting, cooking, refrigeration, vacuum cleaning, ironing, washing, sewing and so forth. Its installation into premises necessitates a special form of insulation to prevent fires, and bendable pipes made of spirally wound metal are frequently used.

The great majority of parts going to make up a structure are made in factories —doors, window-frames, closets and cupboards. On this principle we have what is popularly known as prefabrication or "pre-assembly" (Fig. 3). This method, already in being, is capable of great expansion. On the same principle, practically every ingredient that makes a building may be completed in some workshop or factory and brought to the site ready for assembling; thus enabling all construction work, if properly organized and supervised, to be completed without delay. Nowadays, mortar is brought to the job ready mixed; lighter concretes used on big jobs can be supplied from some central factory, where they have been scientifically prepared, being thoroughly mixed in revolving metallic drums while in transit to the job on hand.

Accessible piping

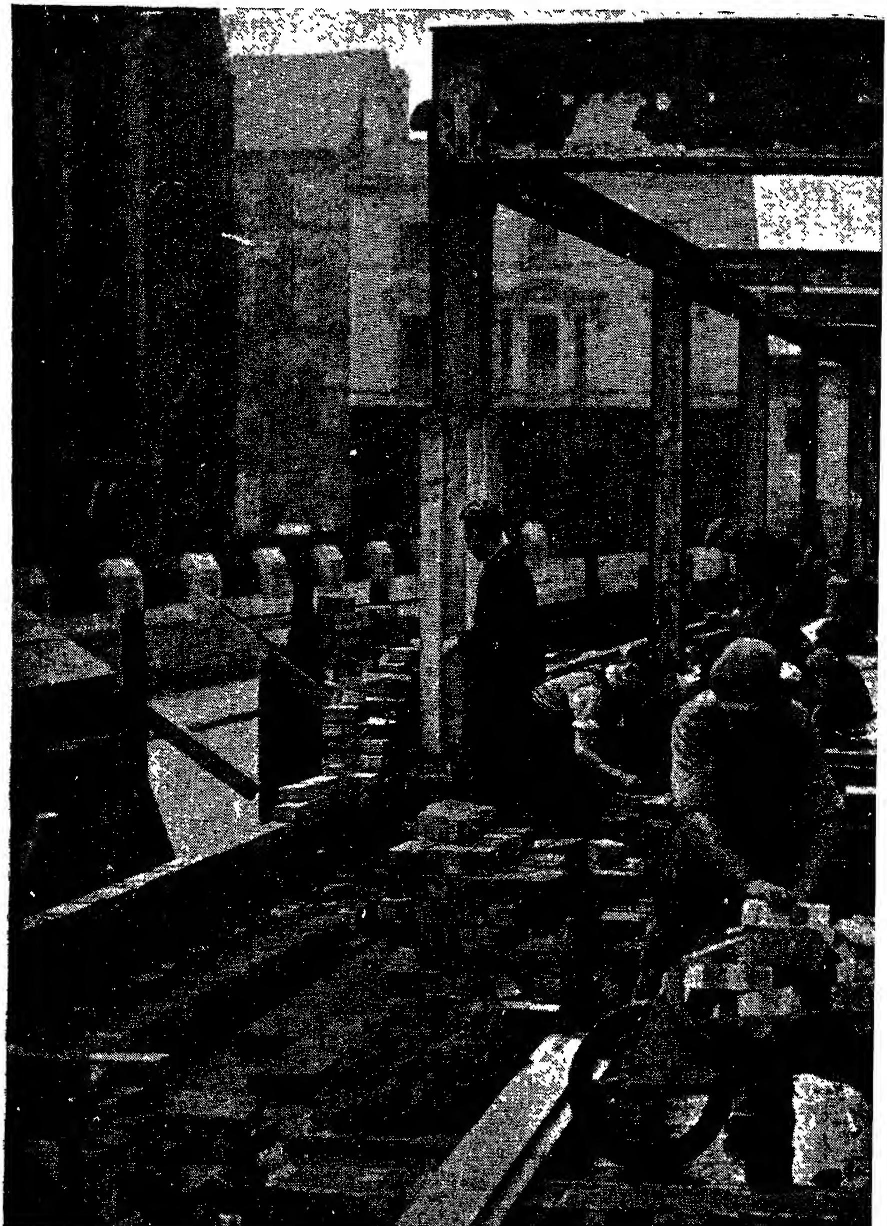
For the last hundred years lead pipes have been used, joined with what is known as a "wiped joint," *i.e.*, hot solder wiped round the pipes where they meet. Though this made a perfectly good joint, it proved difficult if things went wrong, for the pipes themselves were in the walls. These difficulties are no longer with us for lead pipes with their wipe joints are fast disappearing and pipes are either of copper or, preferably, of wrought or "black" iron. Nowadays, measurements are taken of where the pipes will have to go; they are cut to these lengths, have screw connections fitted away in some factory, and only have to be brought to the site for fixing with the necessary screw unions. The advantage of the new system is that in the event of anything going wrong, fittings can be taken out and new sections put in.

Building units

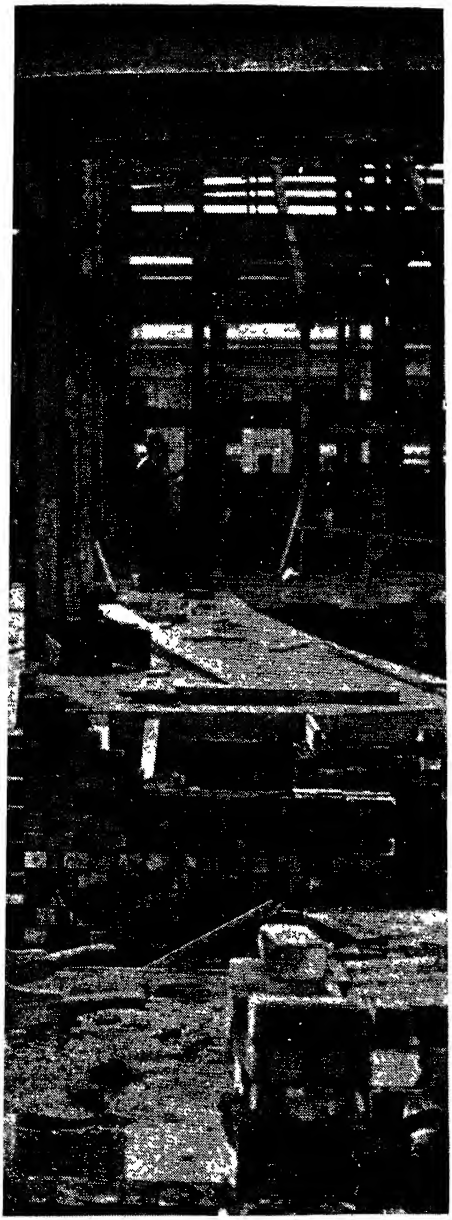
To turn to building units going into the interiors of buildings: entire sections can now be made in factories. The essential fittings of a kitchen can be fixed to one side of a wall, and on the other side of the same wall can be fixed the essential fittings of a bathroom. Attached to this section of wall on the kitchen side would be the range, refrigerator, sink and so forth, and, on the bathroom side, the bath, w.c. and wash-basin. After bringing this section with its attached fixtures and standing it in place, it can be bolted to the surrounding structure, about five pipes for hot and cold water and waste connected up, electricity and gas also

REINFORCING WALLS WITH METAL

In the above photograph may be seen metal reinforcement applied to wall construction. This method gives an increased ratio of strength to thickness, and the consequent saving of valuable space on the outside walls makes more available inside the completed building. The characteristic scene illustrated shows work in progress on an important civic building in the provinces.



connected up—and you have a completed bathroom and kitchen fully equipped and installed in about two to two-and-a-half hours in a single comprehensive operation. The erection of a modern building is an intricate procedure. If the structure is of a large and complicated type, no less than thirty-two trades, each with its own separate group of mechanics, tools and materials, have to play their part. Even a



BRICKLAYERS TAKE OVER

With the framework in place, the bricklayers are working on their part of the job. In erecting such a building thirty-two trades may be involved.

simple agricultural cottage requires over a third of this number and, in every instance, the architect should prepare drawings clearly illustrating what task each particular trade will have to do.

Such an undertaking is properly worked out on what is termed a "time and progress schedule," indicating the date on which each trade on a job is to commence, each of its intermediate stages, and the date of completion, so that all concerned can know when their particular part of the work must be ready and can estimate the number of mechanics needed at any particular period. Our good builders are thorough and most of them work out graphs of the progress of their work, but very few do this before the work starts on the site, few define the time when each group of tradesmen should enter upon the work, when the material they will need must be delivered, etc., so that the entire building fits like a jigsaw puzzle.

Let us now take a minor cottage as a basis for discussion and briefly scan the various operations. After selecting and approving a site, the top soil containing vegetable matter is removed and the area to be occupied by the building staked out. If there is no cellarage, the foundation lines are then marked and trenches are cut to a depth of about two to three feet below the level of the cleared site. At the bottom of each trench is deposited a layer of concrete made of cement and sand, and broken stone, broken brick or gravel, to a thickness of six to nine inches, according to the height and weight of the walls. The width, determined by the bearing strength of the soil, would be about two-and-a-half times that of the wall to be built upon it. This concrete foundation makes a sort of beam all around the site so that the walls cannot move from the position in which they are originally erected. When this concrete slab is set, assuming the building is to be a straightforward brick construction, layers of

brick, double the width of the wall to be superimposed, will be laid and stepped back, course by course, until they are the width of the wall itself. The object of this is to make a spread foundation which will distribute the weight.

Making a "damp course"

The wall itself is carried to a certain height above the finished level of the ground, and at this point is introduced a damp-proof course (Fig. 1) taken right through the wall so that no dampness from either inside or outside can soak up past it. Thus no moisture from splashes or by capillarity can be sucked up into the wall, rotting the floor beams and saturating the plaster and other inside treatments. The damp-proof course is made of lead, slate or other materials, such as bituminous felt, carried right through the wall to prevent rain or dampness penetrating through the general surface of the wall above. Sometimes the wall is built in two layers with an air-space between.

At an appropriate level, ground floor beams of about 1 ft. 3 in. to 1 ft. 6 in. set centre to centre are installed and run from wall to wall. For a long span they often rest on "sleeper" walls—low supporting walls built in between the main walls to carry these floor beams. As the wall continues to be built, it has to be kept square and plumb so that it is strictly vertical. Doors and windows are usually brought to the job in their frames and are set in the walls; and the brickwork is then built up to them. Where the wall is hollow, burnt brick earth, terracotta tiles or metal distance pieces hold the two thicknesses of wall together. As the wall is built, in it should be left channels or chases in which plumbing pipes, electric wiring tubes and water pipes can be placed later on.

Below the ground floor there should be, and usually is, a layer of rough concrete on either side to protect the beams and floor itself against fungus, dampness and rot setting in. In well-built houses or cottages there should be a double floor over the beams: first a layer of rough boarding and then a finished one. The rough or under flooring is used by the workers to walk on in finishing the building whilst the finished floor is put down later.

Internal partitions may be of wooden studs about 2 in. × 4 in., placed 1 ft. 6 in.—2 ft. 6 in., and centred vertically. To these are nailed on either side rows of wooden laths upon which there will ultimately be two or three coats of plaster—a rough coat, a scratch coat and a finishing coat. The same lath and plaster treatment is applied underneath the first floor beams to form the ceiling. Doors and their frames are set in these partition walls as the partitions are built.

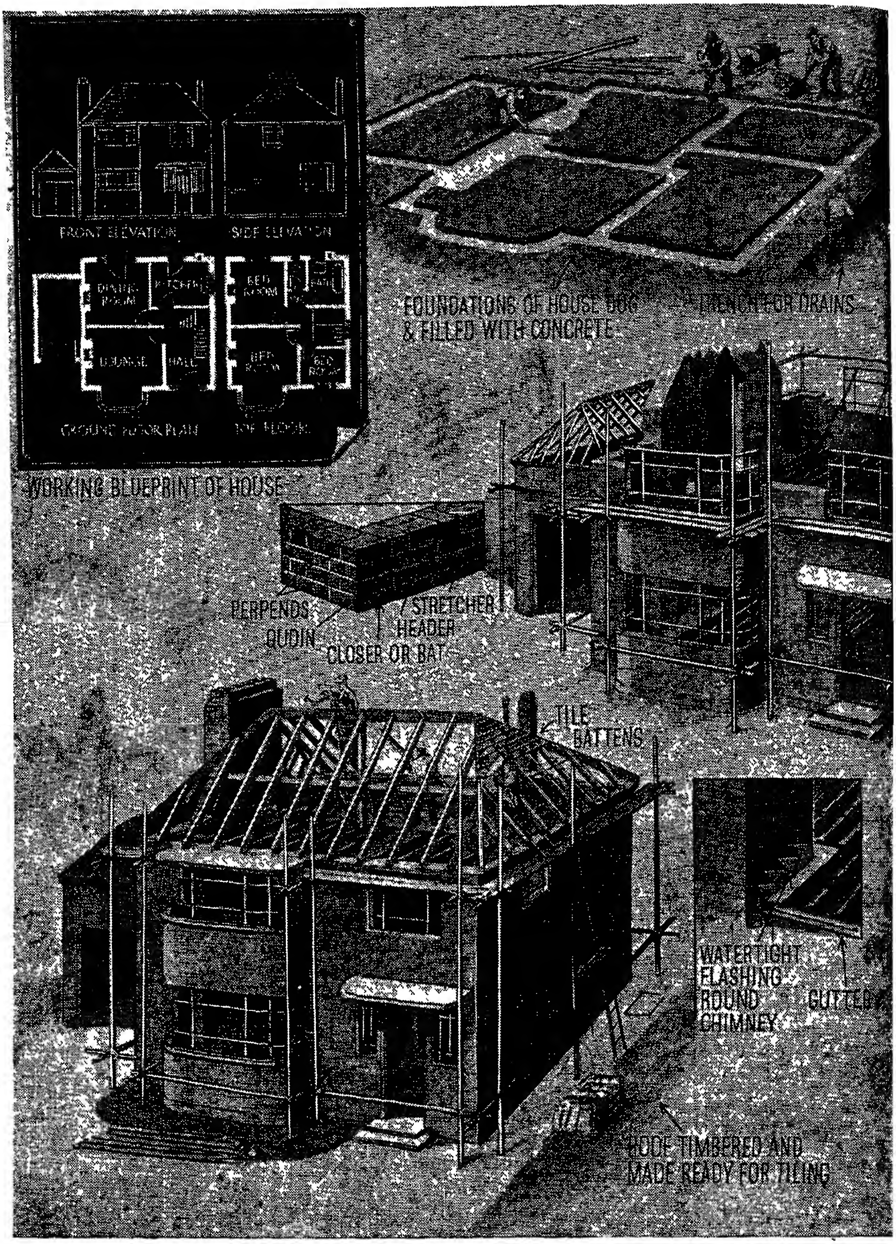
First floor ceiling rafters are placed across the building to rest on the partitions and, when this level is reached, a wooden wall plate is placed on the inner face of the wall from which is erected the sloping roof timbers. These vary in size according to the span they have to cover, but are seldom more than two inches thick and five to seven inches in depth, and reach up to the ridge piece. The roof joists are held in rigid position between the wall plate and the ridge, and to them are nailed either diagonal or wooden strips to carry the roofing itself.

Good mortar essential

There are a hundred different ways of doing almost any of the work in connection with a building of this sort, but it is imperative that the brickwork shall be carried up between the ends of all beams and roof timbers, so that there shall be no spaces left for draughts, or where the wind could lift the roof off. All brickwork should also be well flushed with good mortar made with cement, for it

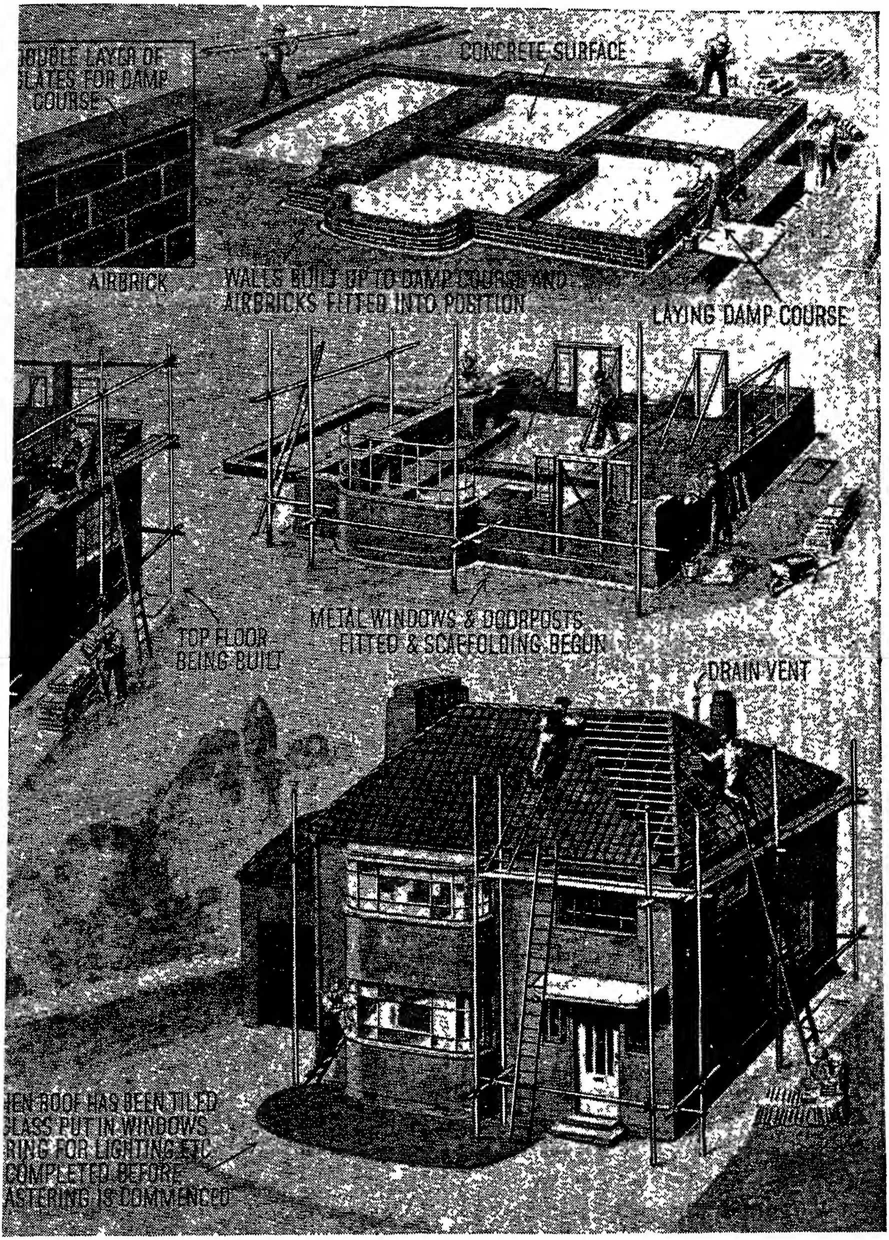
GETTING READY FOR THE CONCRETE

The above photograph gives a very clear impression of the sequence of work involved in reinforced concrete building. Workmen are shown tying the horizontal "distance pieces" to the upright metal supports with wire. Wooden shuttering will presently be erected and filled with liquid concrete, in due course to be dismantled when the concrete has set hard. Thus do such structures grow.



HOW A HOUSE IS BUILT:

FIG. 1. *Step by step, we see the growth of a house—not of "prefabricated" type, but of ordinary brick. Even the erection of a simple house demands—or should demand—careful planning and skilled handling in every detail of its construction. Gone for ever, it may be hoped, are the bad old days when houses were too often cheaply "run up" without recourse to a qualified architect.*



FROM FOUNDATIONS TO ROOF

Above, the normal development of an average two-storey home from the plans to putting on the roof tiles is traced in a series of stages. Roofing, glazing and wiring, however, do not complete the work as plastering and general interior decoration have still to be carried out in all details, before the building is ready to receive its first occupants and become a centre of family life.

has been proved that buildings of cement stand shocks infinitely better than those finished with the old-type lime mortar. The bricks themselves should be hard and should have almost a metal ring when struck with the mason's trowel.

"Struck" or "pointed"

It is better for the mortar between the bricks to be carried out to the face of the fork and "struck" as the bricks are laid. This means either running the trowel along the edge of each course, or using a jointer between each course in order to compress the edge of the mortar and render it as waterproof as possible. In the majority of cases, the system adopted is to leave a space which is "pointed" as the scaffolding is finally taken down and the brickwork cleaned. This probably makes a neater job but, scientifically, is not quite as good as the other method, though each can give full satisfaction if skilfully handled.

With regard to the tiles or slates which form the covering of so many roofs, it is usual to place at the bottom, just against the gutter, what is called a "tilting fillet" to cause each tile to bed itself against the layer or course below as closely as possible, so making the roof weatherproof. A similar fillet is applied on the top where, before the tiles or slates reach the ridge, there is another small fillet to throw the top edge of the top course up a little and make it, in turn, bed itself more firmly upon the course below. By this means, the roofing material forms a slightly concave surface, and the top of the ridge is treated with a semi-circular covering tile bedded in cement. Or a sheet of lead is carried over the ridge and under the slates or tiles, and on this a circular, roll-like ridge-piece of wood is nailed; then, on this again, another piece of lead is beaten so that water falling on the juncture at the top of the roof cannot possibly enter the building.

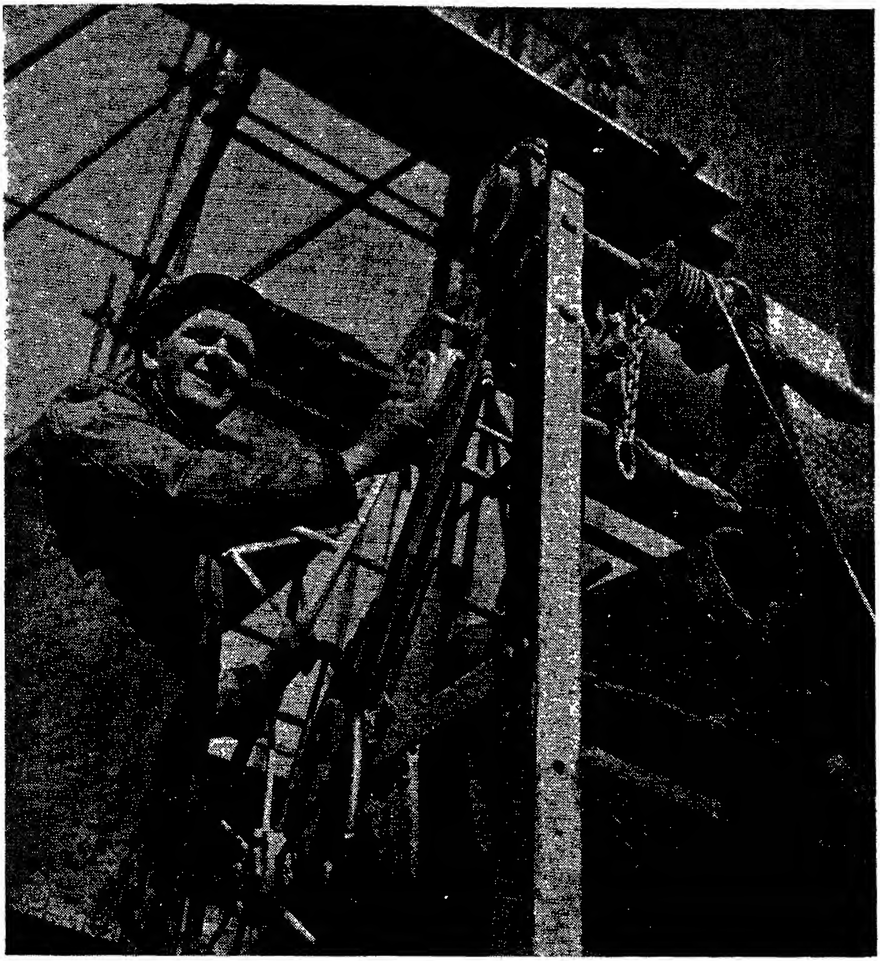
Where it can be afforded, glazed tiles are, of course, preferable on the walls of bathrooms and kitchens, though plastics are beginning to be used in ever greater quantities. Plastics in sheets can be satisfactorily applied to kitchens, bathrooms or corridor walls; in other words, materials unaffected by damp, heat, wear and tear are undoubtedly preferable on surfaces where such conditions are prevalent. Where there is a lot of splashing, ordinary wooden floors are not considered suitable but, if wood is used, it is better to have a heavy linoleum covering; or even better still, tiles laid on cement form a very suitable flooring. When the floors are down, connections for electricity or gas, and appropriate picture moulds and skirting boards are fitted; but these should be fixed to plugs installed prior to the plastering.

Where there are chimneys, however, great care has to be taken that they are so jointed up that no sparks can work through brickwork crevices and set fire to nearby roofs or floor beams. There is not now the same number of fireplaces in a house as at one time, and more and more places are being heated by electricity, gas or water, while the time may not be far distant when continuous hot, as well as cold, water will be supplied to the great majority of our houses by the municipal authorities of the area.

Pressed metal and plastics

With the ever-widening use of pressed metals, we may expect many new types and forms of built-in furniture in this medium as well as fashioned from plywoods, plastics, etc., which will in the majority of instances form part of the original house.

There is a great need, which is steadily being met, for rooms to be soundproofed. This is done by applying various wall plasters or boards of an aerated fibrous material, or of aerated concrete



CONCRETE MIXER

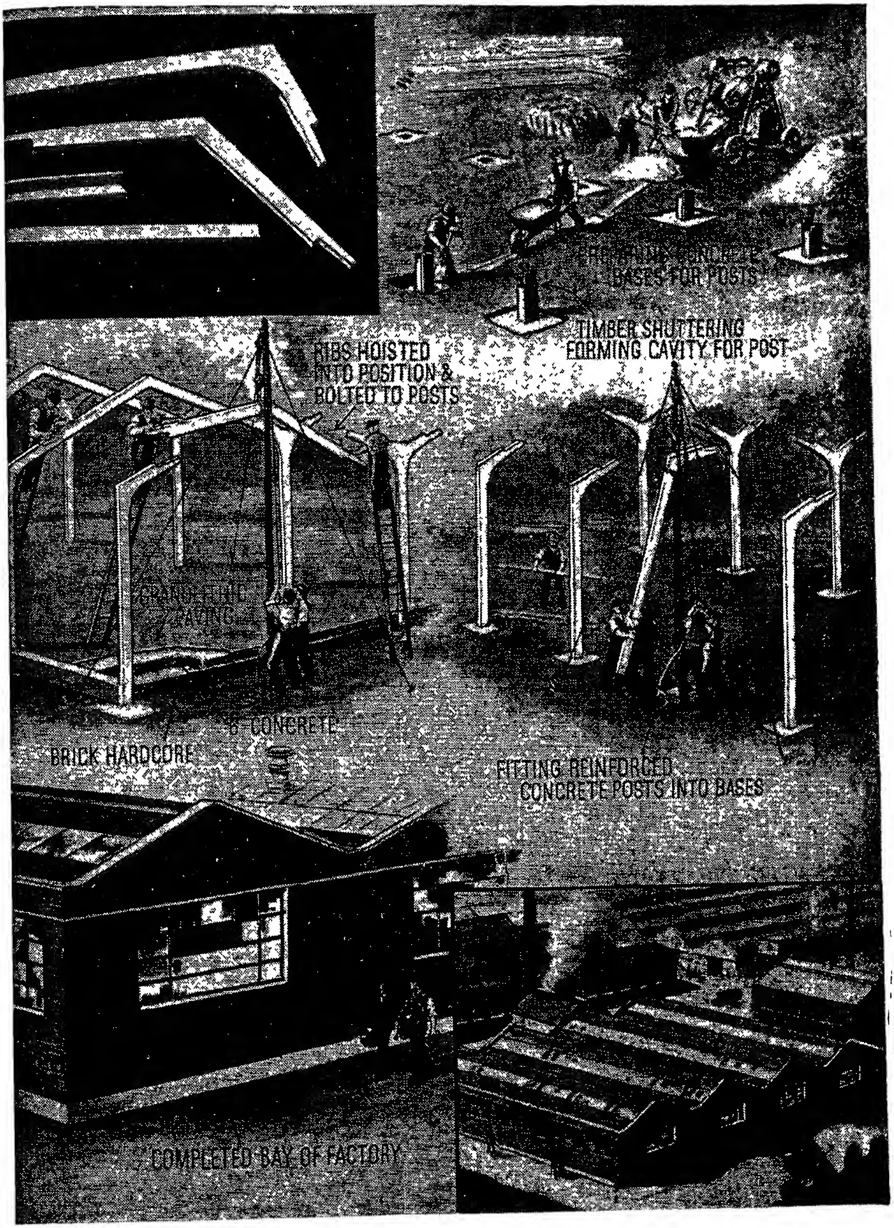
FIG. 2. *Though lighter concretes for big jobs can be supplied from some central factory, and mixed in revolving drums while in transit to the site, the mixer on the spot remains a familiar feature of many building operations, such as is seen in the above picture of cheeiful efficiency.*

made by a chemical process in which the water in the material is separated into its component parts of hydrogen and oxygen to form bubbles in the concrete, thereby making it a sound-resisting fabric. Then is followed the same sort of procedure as that followed for the hollow exterior brick walls, for the air spaces, though not creating vacuums, prevent to a large measure the passage of noise, a detail of considerable importance.

Practical endeavour has shown that the shell of the home itself can be constructed more on the basis of an ice-box: the skeleton, side panels, top and bottom all being of insulated materials so that room temperatures can be regulated just as desired. Draughts, always a great

ONE WAY OF BUILDING A FACTORY:

FIG. 3. *Factories can be built in more than one way, from the "flatted" to those in simple bays. In erecting such a factory as that seen above, prefabricated frame units of reinforced concrete are brought to the site and there placed and bolted in position, before the brick outer skin is applied, metal window-frames are inserted, and roofing and ventilators put into place.*



REINFORCED CONCRETE AND BRICK

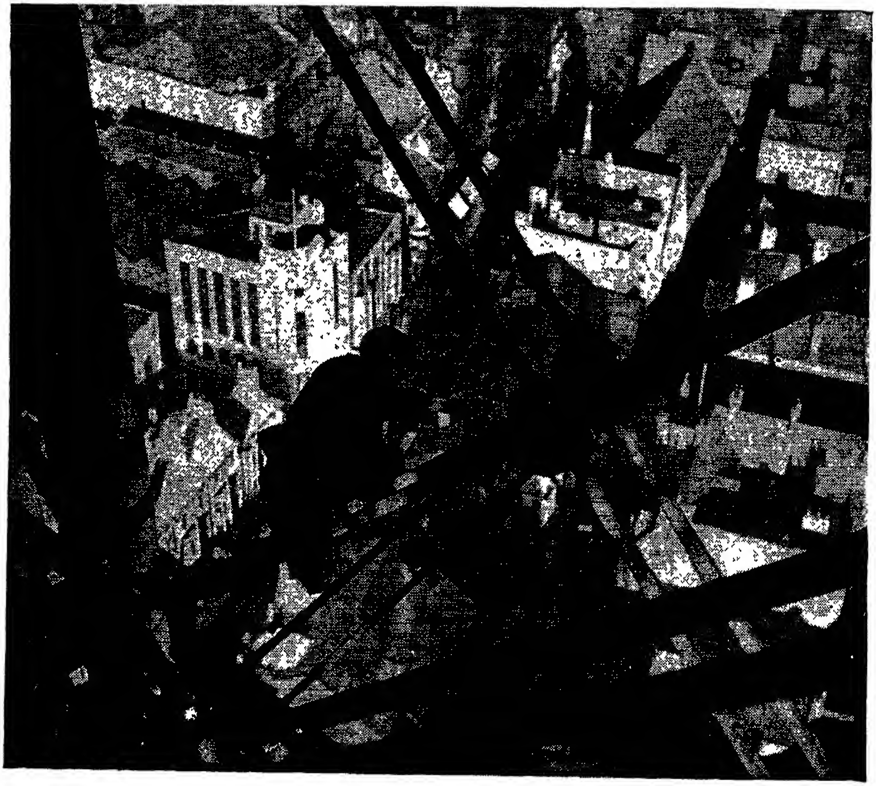
By such means can a factory be swiftly and surely constructed, though prefabrication can be carried much further than is shown in the above relatively modest example, which has been designed and pictured specially for the present book under expert architectural supervision. Note how the repetitive design of this factory makes it capable of almost limitless expansion.

difficulty, can now be overcome by introducing appropriate weather-strips around exterior window- and door-frames. Also there should be another strip projecting into the brickwork from the back of the wooden frames, which should be firmly cemented in so that there is no through joint behind either the door- or window-frame, or through the door or window.

"Flatted" factories

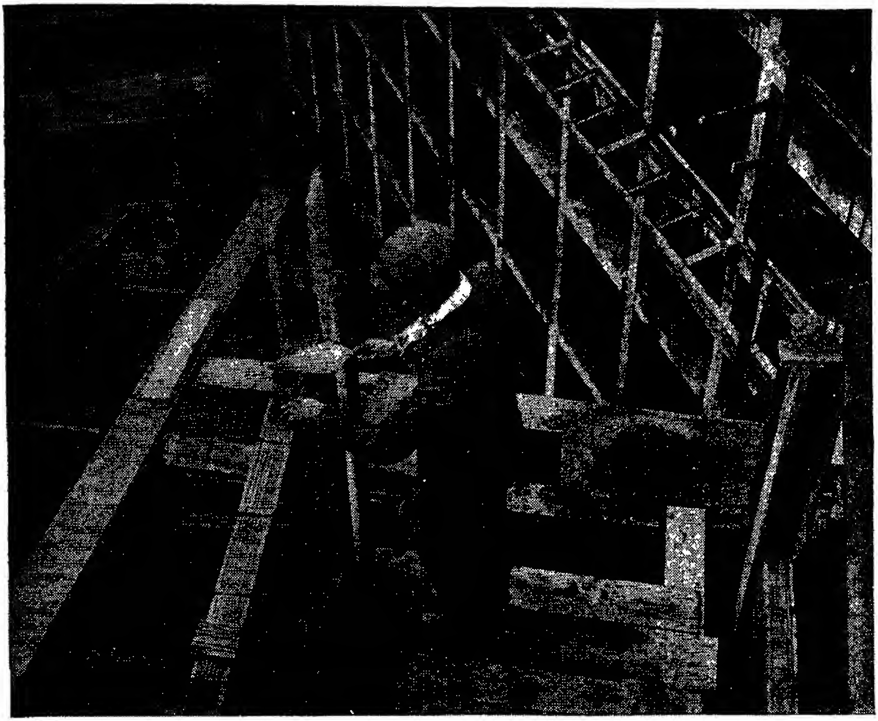
Many of our factories, employing to-day from 10 to 200 workers, have grown up in the backyards or in residential property. Frequently ordinary domestic houses have been converted into workshops and remarkably good results have been obtained under these abnormal conditions, but at what a cost in toil and sweat on the workers' part! In the latter half of the 20th century this will no longer be excused or justified. Other countries have faced this problem with marked success and, by employing something like what is now known as the "flatted" factory, better results could be obtained in Great Britain.

A "flatted" factory is somewhat similar in principle to a series of flats, and a number of different firms can occupy the same building. Such a structure is, usually, approximately six stories high.



AT DIZZY HEIGHTS!

Work on a structure does not necessarily cease with its completion. Maintenance may have to be considered. Above, for example, a painter is seen at work on exposed ties of steel that, with periodical repainting, are capable of a long life. Often such tasks demand a very cool head!



HOLLOW TILE USAGE

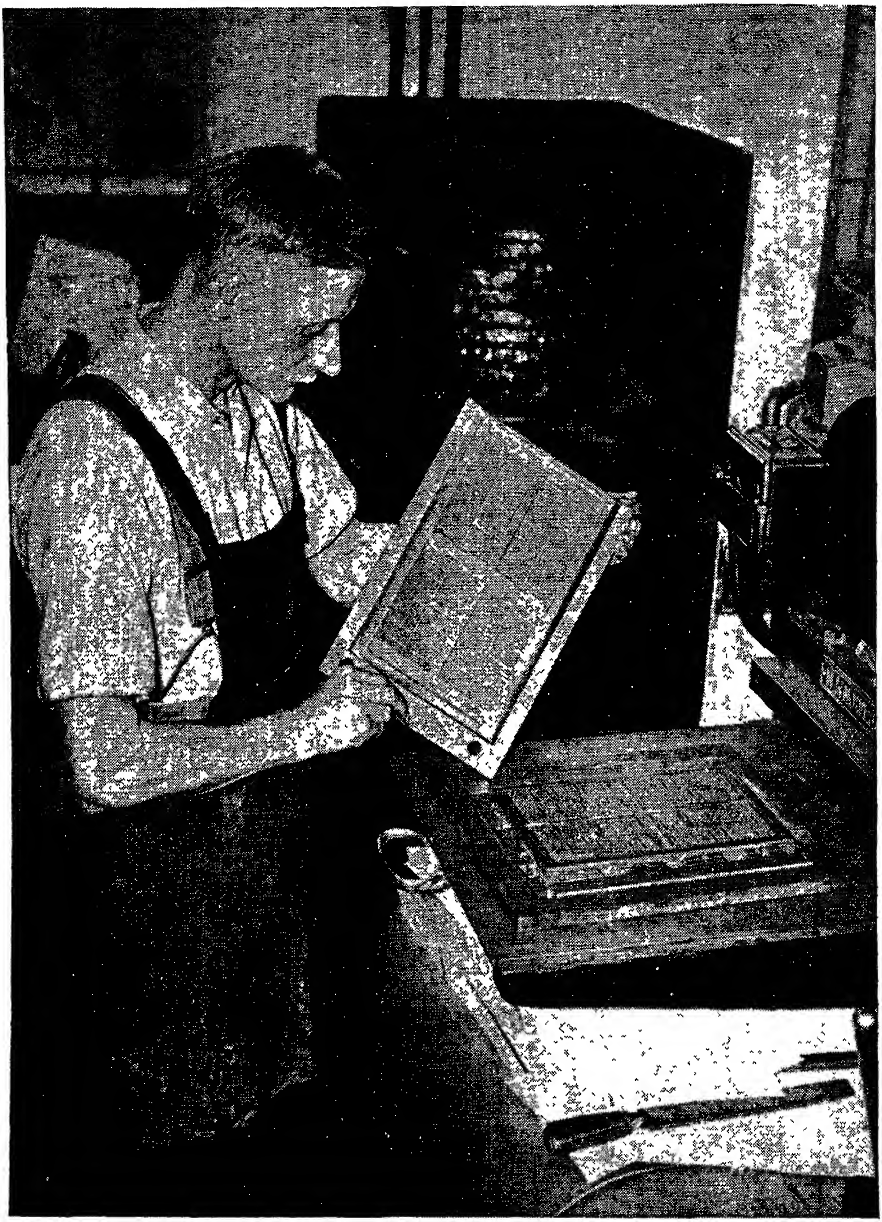
FIG. 4. *In frame construction, the lighter the building or walling materials, the less substance is required in the frame itself and the less weight is placed upon the foundations of the building. At the same time, new treatment of bricks provides much better sound-proofing and heat insulation.*

It is built on a steel frame, fire-proofed and has the "sprinkler" system. It provides adequate working accommodation, is well lit with natural light on all sides, is equipped with good heating, ventilation and sanitary arrangements and has its own freight and passenger lifts, with rest rooms for the staffs of the various concerns it happens to house. Indeed, if not actually making work a pleasure, these advantages certainly obviate a great deal of needless and wasteful drudgery.

Health and progress

Such a building can be equipped with all the necessary machinery and tools, and, being freed from sub-dividing partitions, it allows for expansion when a firm prospers or when other tenants move out, without wastefully cramping workers and equipment alike.

When such arrangements become more universal, they will undoubtedly go far towards improving the health of operatives, increasing output, and reducing costs of manufacture and overhead charges. They will, therefore, aid in maintaining our standard of living which will only be possible if we can sell our goods abroad at a fair competitive price as compared with those of other countries. Such results can only be achieved under the very best working conditions possible and it behoves British industrialists to study their workers to the best of their ability, in the interests of all concerned.



A GREAT TRADITION

Carrying on Caxton's craft, with different methods, maybe, but in a full sense of participating in a great tradition, this stereotyper examines the mould he has just removed from a forme of type. Cast from the mould, a stereoplate is used for actually printing these four pages from an English Bible—a best seller for four hundred years. Not only a great industry but a mighty force in intellectual affairs, printing comes close to artistry in its demands on taste and skill.

THE STORY OF PRINTING

Compiled by HARRY WHETTON

Inside a typical printing works. How type is set up by hand and machine. The craftsmen and their respective duties. Proof-reading and make-up. Work on the "stone." Printing machines—from platen to giant rotary. Stereo- and electro-plates and their making. Reproducing illustrations. Marvels of the half-tone block process.

PRINTING is a necessity alike to peace and the conduct of war. At once a craft and an industry, a mainstay of literary expression, reportage, the dissemination of ideas and the spread of education, it is uniquely important.

To gain any idea of how printing appears to the "man on the job," we must go to the actual operatives. By way of a start, let us take that bedrock of the industry—typesetting. To watch this process, we must visit a composing room, where the "comps"—no printer or journalist ever calls them "compositors"—are at work. There are many kinds and sizes of composing rooms, the one we are visiting being that of a magazine which is just going to press, or, in printers' language, being "put to bed."

Type assembly is by hand and by machine. This man, standing in front of a pair of type-cases and lifting pieces of type into a metal "composing stick," is setting headlines for an article. These he places on a tray called a "galley," and there they remain until the "make-up man" is ready to make-up the page.

Here comes the make-up man, with a long column of type on another tray called a "slip galley." See how adroitly he lifts the type, a dozen lines at a time, from the slip galley on to the make-up galley. In this case the lines consist of separate lines; that is, each line of type is a solid slug of metal, set on the linotype (line-o'-type) machine (Fig. 1). Sometimes type is in separate characters as in Caxton's day, though nowadays movable type can be set at the rate of many thousands of letters an hour by means of the monotype machine. As its name indicates the monotype furnishes separate types, and, although utilized in some newspaper offices, is chiefly installed in general printing works and those undertaking book and publicity literature.

The principle of the monotype system consists in the casting of type characters by means of a corresponding series of perforations on a paper reel—these perforations being produced by the depression of keys on a keyboard, which is operated in much the same fashion as a typewriter. Thus the operator has in effect a type foundry under his hand, for when the perforated reel is transferred to the machine called the caster and brought into contact with the matrix case, single type is correctly and automatically set with marvellous precision and accuracy, as is seen in Fig. 1.

When (to return to him) the make-up man has placed enough matter on the make-up galley to fill the first column, which he measures for correct length by means of a type-gauge, he places a "reglet" (a strip of wood) or a strip of metal along the full length of the column. This strip

AUTOMATIC TYPE SETTING

FIG. 1. *Illustrated above are two methods of setting up type automatically which for general purposes have displaced hand setting. The Linotype machine sets up and casts individual lines of type into metal slugs in one operation. Monotype machines operate in two processes, each letter being cast into a separate slug which can be changed without resetting the whole line.*

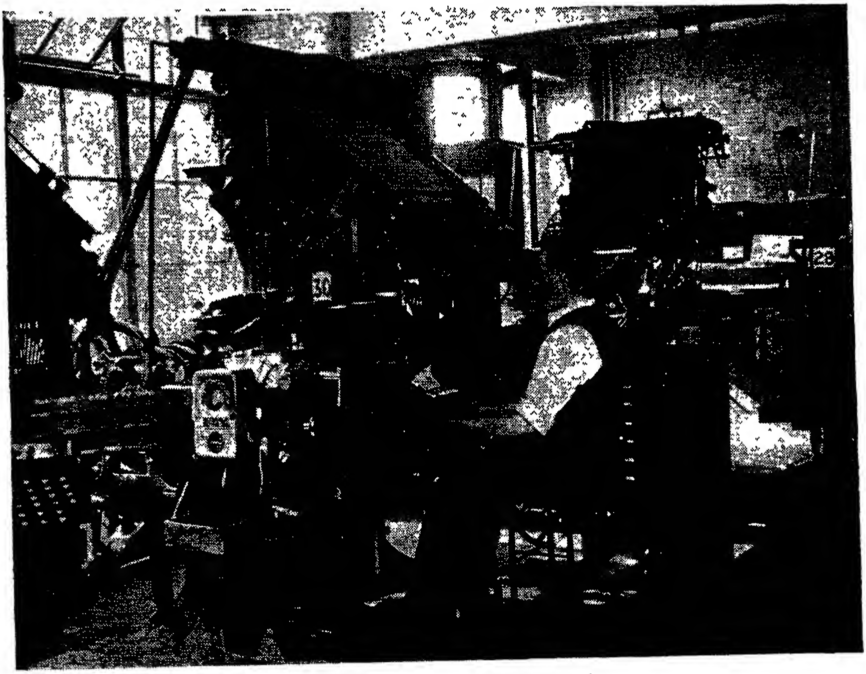
of wood or metal, being lower in height than the type-face, fulfils two purposes: (*a*) to support the next column; (*b*) to act as a space between the columns.

In this case the page consists of two columns, and when the make-up man is satisfied that it is "O.K. for depth," he produces a piece of strong thin cord (a "page-cord") and secures the page as a whole by tying it firmly round the whole of the page which is supported broadwise by a reglet at top and bottom.

When a column of type comes from the linotype machine it is proofed on a long slip of paper called a "galley-proof." This is handed to the reader with the copy.

This man in a cubicle, surrounded by proofs, "copy," dictionaries and other books of reference, is the corrector of the press, or printers' reader. His task is to see that everything printed is correct in all details. It is a rule in printing, that except in certain special cases, nothing can go to press except on his signature. The proof is compared with the copy by the reader, who has an assistant (a "copy-holder") to read the copy to him while he reads the proof. When he is satisfied, he marks it at the top with the sign "1st" ("first proof") adding his initials and the date. When the proof has been corrected by the compositors, they "pull" another proof so that the reader may check the corrections. This done, he marks the proof at the top with an "R" ("revise") again adding his initials and the date.

When the make-up man has made up his page, he pulls a proof of it ("page proof") and hands it to the reader with the proof marked "R". The reader checks any



LINOTYPE OPERATOR AT WORK

A Linotype machine, the wonderful workings of which are explained in the drawing on the opposite page, is here seen in action. Note the "copy" which is clipped in front of the shirt-sleeved operator, whose fingers quickly and accurately tap the appropriate keys in front of him.

necessary corrections and "reads the page for press." Then he writes "Press" at the top of the proof, adding yet again his initials and the date. The page is then ready for press.

What happens on "the stone"

Now we must go to the centre of the department where men are gathered round "the stone," a large table with a metal top, two or three inches thick, the surface of which is dead true.

The make-up man slides his corrected page on to the stone and pushes it into its appointed place, which is marked with chalk. Magazines usually go to press in series of eight or sixteen pages, these being the most convenient numbers for the purpose of folding.

In the case before us eight pages—the first "forme"—are going to press. A forme comprises the eight or sixteen pages, and so on, held firmly together in a "chase" (a metal frame).

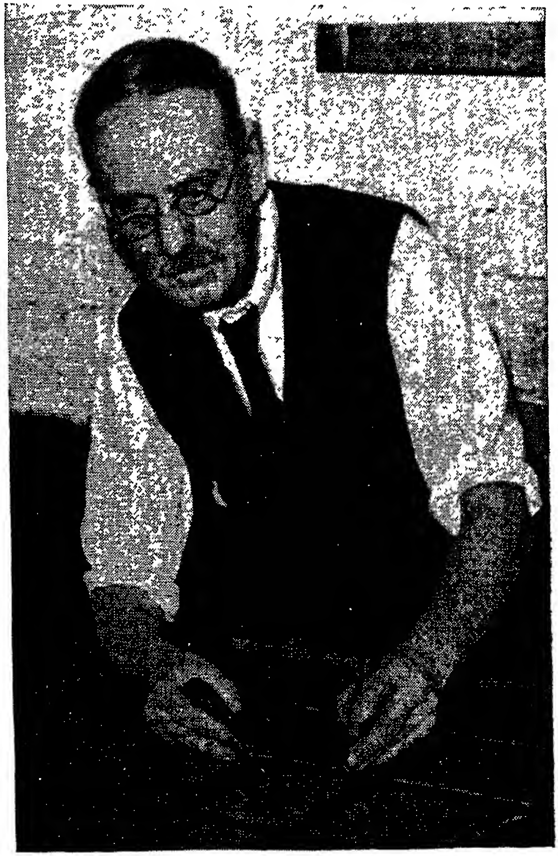
The men round the stone are called "stone hands." They are expert in the positions in which the pages must be placed so as to fold correctly when printed. They are expert, too, in handling type. They untie the page-cords after "dressing the forme." Dressing the forme means placing pieces of wood (lower than the type-face) between the sides and heads of the pages so as to allow for correct white margins when printed. These pieces of wood go under the name of "furniture." Then each page has a "sidestick" placed along its length and a

LOCKING UP A FORME

FIG. 2. *Having arranged the pages of type on the "stone" in the appropriate order for printing, the compositor locks up a "forme" of eight pages in the "chase," or metal frame. He is shown hammering short wooden wedges, known as "quoins," into the spaces left between the frame and "sidesticks."*

footstick against its foot. Sidesticks (of wood or metal) are in the shape of long wedges. It will be obvious that the space between the edge of the metal frame and the nearest edge of the sidesticks, and footsticks, will be wedge-shaped too. Into this space are fitted "quoins," which are short wooden wedges (Fig. 2).

Before the quoins are finally driven home, one of the stone hands "planes down the forme." That is, he places a specially made piece of wood (the "planer") on the face of each page in turn and firmly taps it with the mallet. This ensures a true printing surface.



COMPOSITOR AT WORK

Above is shown a last-minute correction in the "forme" being made by a compositor before it is finally passed for press.

Meanwhile, others of the staff are getting other sections of the magazine ready for press. A comp. is walking from type-case to type-case, selecting suitable type for an advertisement which he is setting. A clicking noise tells that a linotype machine is operating; a *chug-chugging* that the monotype casting machine is turning out separate letters at incredible speed—letters that mechanically arrange themselves in lines and columns. A drone-like sound comes from the copyholder reading "copy" to the reader.

The men employed on the magazine—comps, stone hands, readers, linotype and monotype operators, etc., are called a "ship," short for a "companionship." The man in charge of the ship is a "clicker," sometimes called "the printer."

Now for another look at the linotypes, as shown in Fig. 1. Use of the linotype has ousted hand type setting for newspaper production. And not only for text as such, but display heads and much of the material for advertisements.

The machine is self-contained, in that it operates from a keyboard, whence setting and controls (such as for casting from matrices) are found. As an operator's fingers move over the keyboard, brass matrices, each bearing the mould of a letter, are released from an overhead magazine. They come rattling down their channels and fit themselves comfortably into the receptacle in front of the operator. A bell rings and the operator knows that a complete line of matrices is assembled. He presses a lever and before

one can count ten the receptacle has disappeared. Molten metal has come into contact with the matrices and here a shining white metal line of type comes sliding out—still hot!

And now let us visit those very necessary persons, the stereotypers, whose craft has done as much as anything to put printing on a modern footing.

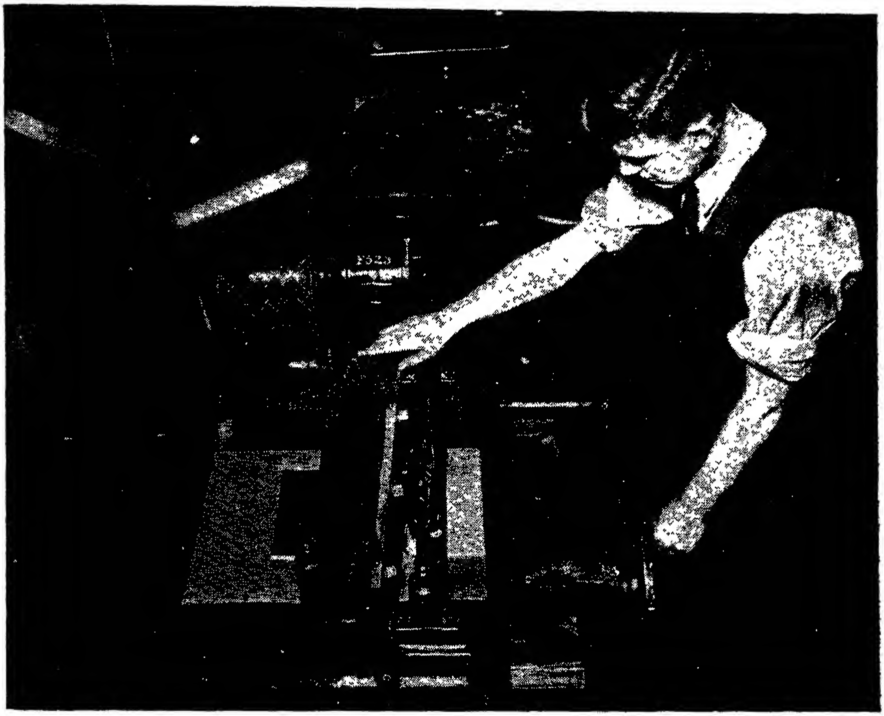
Our sense of smell promptly tells us that we have entered a stereotyping "foundry." Notice the dry acrid odour, suggesting burning metal, to which, however, we soon become accustomed.

Here is a stereoplate. It is about one-sixth of an inch in thickness and is made of a mixture of lead, antimony and tin. The front—or the face—presents a picture of a page of type in reverse, whilst the back is slightly ribbed or grooved to enable it to lie down evenly.

Now come and see a forme of type being moulded; in this case a small forme. The type matter has been specially assembled for casting and the forme is placed on the flat bed of a sturdily built machine, affectionately called a "mangle" by the operator. After adjusting the type for a little while, he places what appears to be a sheet of stout millboard over the formes and covers that again with a rubber blanket and a sheet of zinc. The whole

FIRST STAGE IN CASTING

FIG. 3. *Here the type-face has been specially assembled for casting operations and placed ready in the machine, familiarly called a "mangle." It is then covered with a special preparation, known as "flong," which takes a perfect impression under pressure from a revolving cylinder.*



PLANING A STEREOPLATE

FIG. 4. *After the stereoplate has been cast in metal from the "flong," it is carefully planed, as is shown in the above photograph. After it has been smoothed, the plate is ready for the final stage in the series of operations—being mounted "type-high" on a wooden base.*

passes beneath a revolving steel cylinder which crushes the "board" against the type, and the job is done (Fig. 3).

Let us lift the "board" and handle the mould. The great pressure exerted by the cylinder has forced the type-face into the unresisting surface of the "board" and each letter-character is thus plainly visible sunk deeply into its appointed place. The moulded forme is now ready for use.

"Flongs"

Some explanation is necessary regarding the composition of the "board" or "millboard" which is used in the making of moulded forme.

Actually the material used for this purpose is called "flong," and is specially constructed from many layers of blotting- and tissue-papers firmly held together by a rather wonderful kind of paste. It has now become a matrix from which we can cast our plates.

Dry flongs are universally used for newspaper reproduction, where the printing is done at high speed on rotary machines. For such work the matrix of a whole newspaper page is placed in a curved moulding box and a cast is made to fit the cylinder of the printing machine. The stereoplates resemble a half-circle and are clamped into position on the cylinder, which revolves with the paper roll to print the requisite number of copies normally calculated to satisfy the requirements of each edition.

ROUTING MACHINE

FIG. 5. *In casting pages into stereos, the unwanted portions of the plate are carefully cut away by a routing machine, which is seen in action above. A good eye, steady hand and considerable experience are needed for this—one slip of the tool would ruin the work.*

We now pass on to the casting boxes standing beside huge cauldrons ("pots," the stereotypers call them) of molten metal, where you see the matrix inserted and securely clamped down in what we may call the lower half of the box. The steel box is now closed and brought to a perpendicular position, and we watch the operator expertly ladle the molten metal into its mouth.

Routing and planing

In a few seconds the upper lid is removed and the casting taken out to have all superfluous metal trimmed away. The screaming circular saw appears to be angry, for it snarls and bites into the plate like a wild beast devouring its prey.

Next we move to a routing machine which removes all unwanted portions from the surface (Fig. 5). A plane is next used to square up the edges (Fig. 4). The stereoplate is now ready for the final operation—mounting on a wooden base, which brings the face type-high, ready for the printer.

Electrotyping for printing is the art of producing duplicates of type formes, process and other blocks by means of the electro-deposition of copper upon a mould of the original. The process requires the installation of an expensive plant and the careful training of a staff of intelligent craftsmen. Long experience is necessary before a learner is likely to become an efficient electrotyper.

Whilst all these things are going on in the various departments of the printing-works, the blocks which are to illustrate the copy, are being made and mounted so that they will be ready for their job when the type is eventually set. So our next visit is to the blockmakers.

Reproducing illustrations

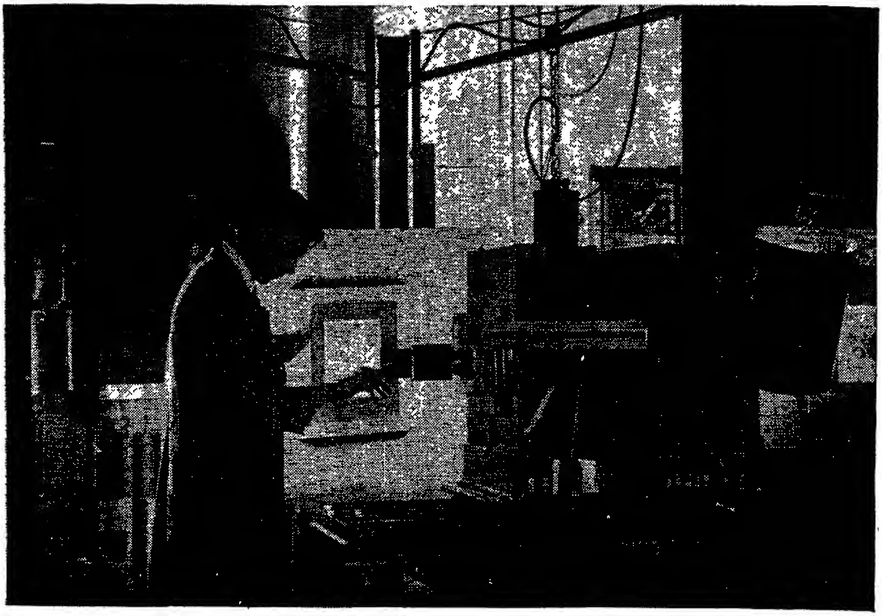
Obviously, all existing types of illustration, popularly known as "pictures," cannot be reviewed in detail here; but a brief account of one of the greatest will help us to appreciate the high degree of technical skill that lies behind the "pictures" in our books, periodicals and newspapers. For example, the photo-engraver, whose handiwork comes before the public on the innumerable occasions when half-tone process blocks are employed—as in the book before you—has a job demanding a high degree of efficiency. Let us follow some imaginary but typical photo-engravers into the studio.

Putting on a "warehouse coat" type of overall—the craft's universal "uniform"—our operator takes a quick look round the apparatus and chemicals and is ready.

Say that the first job is an illustration accompanying this chapter. The "original" is fixed on the copy board of a process camera, and some 5,000 or so candle-power of light switched on from two arc-lamps. Here it may be mentioned that the carbons used for the lamps are

GUILLOTINE DESCENDS

Cutting and trimming are necessary processes in the craft of printing. Here we see a "guillotine" in action, the sharp knife descending upon the paper which has been placed under it. Every possible precaution in the form of guards and safety catches is used to prevent possible injury.



FIRST STAGE IN PHOTO-ENGRAVING

FIG. 6. *Illustrations for printing are etched into metal mounted on wood, the finished article being known as a "block." The first stage, shown above, consists of photographing the original with a specially designed camera with a long bellows which allows of considerable reduction or enlargement.*

precisely the same as those used for searchlights! The type of camera used is so big and heavy that it is mounted on rails and moved back and forth on wheels. The operator next focuses the original to the required size, then making a copy negative from it by the old wet collodion process. "Wet plate," so called because the glass plates are hand-coated and sensitized and must then be exposed while still wet, is still commonly used because it suits the purpose exceptionally well; although many prefer the more modern ready-made dry plates of which "process" types are specially prepared for use.

Half-tone processes

A sheet of glass accurately ruled with crossing opaque lines—the process screen—is placed a short distance in front of the photographic plate, the effect being to split up the image into dots, 120 per square inch in this case. The dots vary in size according to the screen employed. After suitable chemical treatment, when much can be done to affect the tone rendering, the negative is dried and is ready for printing on metal.

The next step is to clean and polish a thin sheet of zinc—just plain hard work with pumice powder and a scrubbing brush!—and then coat it with glue—just good quality fish glue containing some ammonium bichromate. When the coating is dry the metal is pressed tightly against the negative in a sturdy printing frame having a glass front over an inch thick to withstand the pressure, and the whole is then exposed for a few minutes to another arc lamp. Next the zinc plate is removed and washed under a tap. Now, the light affects the bichromated glue coating and it will no longer dissolve away in water except where the dots

forming the negative kept off the light and there it washes out cleanly. A bath in dye makes the glue print visible, and after careful examination it is then burnt in by holding in tongs and heating over a gas flame until the glue carbonizes into a strong black acid resisting enamel—or until, to the operator's infinite disgust, the very hot metal melts!

Etching and trimming

Next comes the etching process, when the metal print is put into a machine and sprayed with dilute nitric acid until the bare metal between the enamel dots is eaten away enough to leave them "standing proud" and of just the right size. After suitable trimming and mounting on wood to type-height, the block is ready for printing.

Now, let us suppose that the blocks have been made, and that the forme, which has already been described, is ready to go to Press.

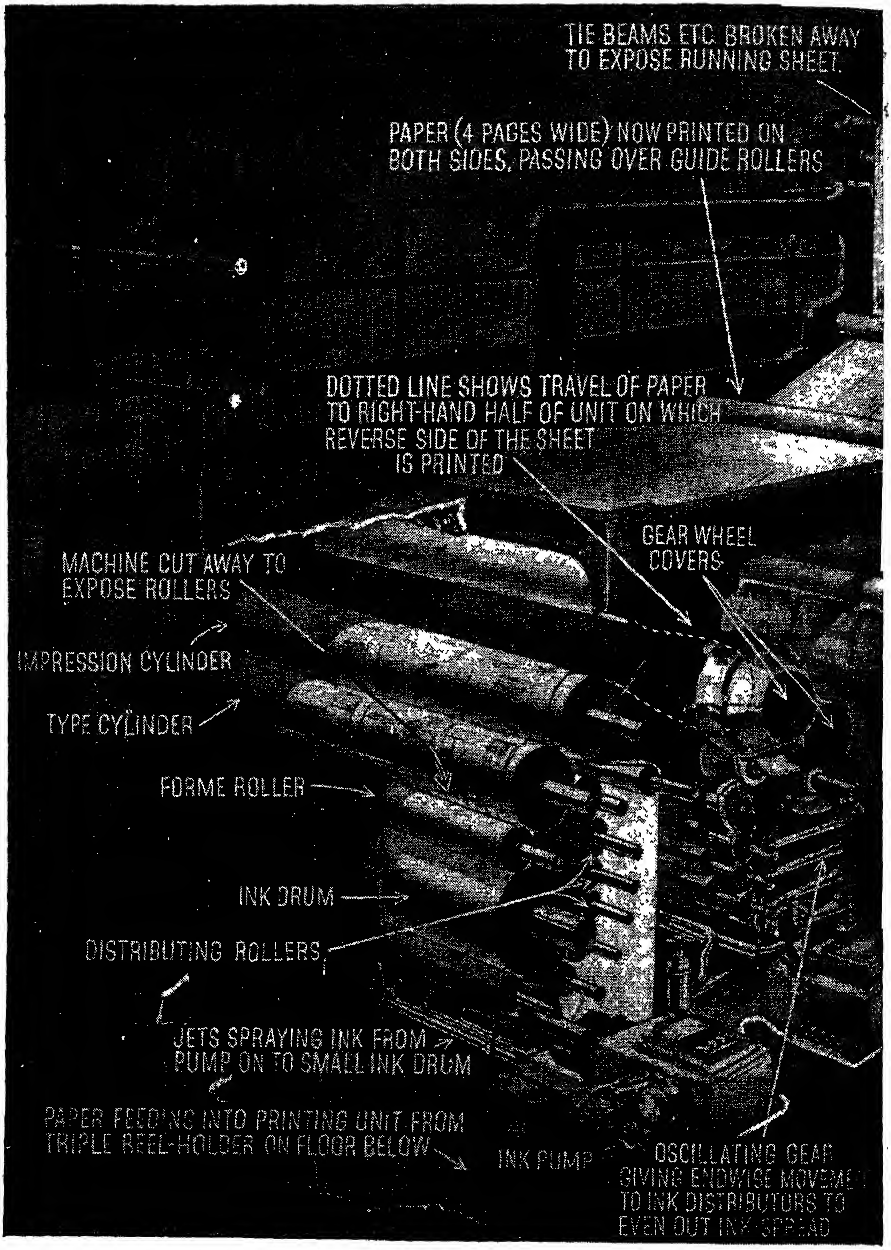
Going to Press

"Going to press" means what it says. The forme has gone to the printing press; so we follow it to the machine-room, which, as any of its operatives will claim, is the most important of all. It is there that the reputation of the artist, the blockmaker and the compositor can be enhanced or damaged. Much of their skill would never be recognized if their colleagues in the machine-room could not competently print the formes prepared for them.

It should be explained that the machines

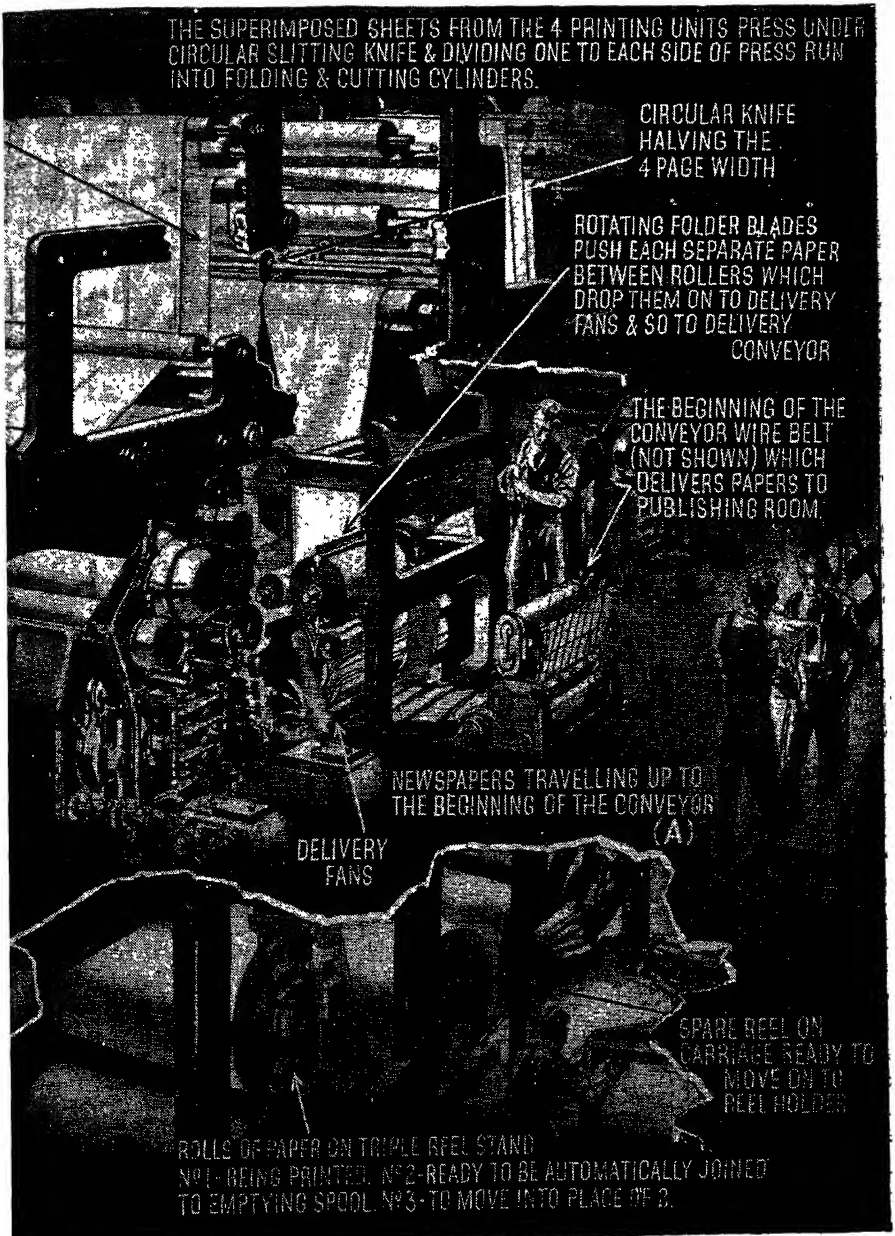
YOUNG CRAFTSMEN IN THE MAKING

Well known to printing operatives, the London School of Printing and Kindred Trades enables boys who are serving their apprenticeship to acquire a first-class practical and theoretical training as craftsmen. A typical class is seen at work in the photograph reproduced above.



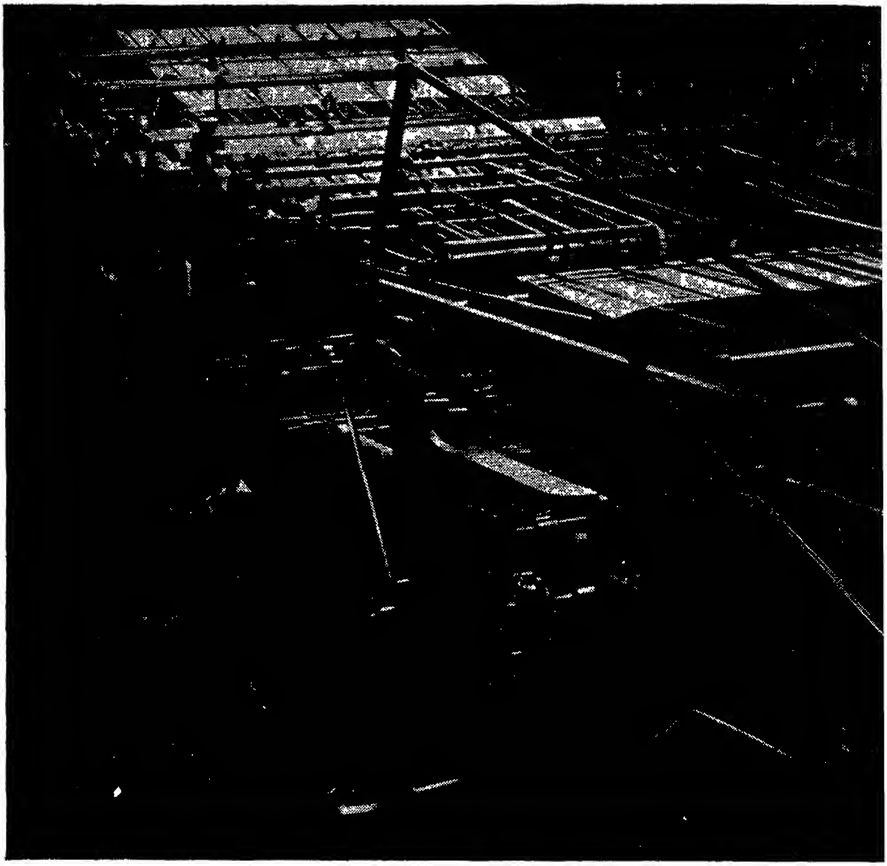
HOW YOUR DAILY PAPER

FIG. 7. *Here is a diagrammatic impression of one of the mighty machines that give news to the world. In newspaper and magazine work the need for speed in printing is paramount. The invention of the rotary press, the workings of which are explained in the above drawing, has enabled up to 25,000 copies per hour to be "run off," cut and folded by one complex machine.*



COMES INTO BEING

To achieve one continuous process, cylindrical castings (stereo- or electro-type) are made from the actual type, as explained on pages 242-4, and these revolve in contact with the roll of paper, both sides being evenly printed with a special ink that dries without smudging. Such, as apart from the all-important human element, are the gigantic mechanisms that print your newspapers.



TWIN CYLINDER FLAT-BED

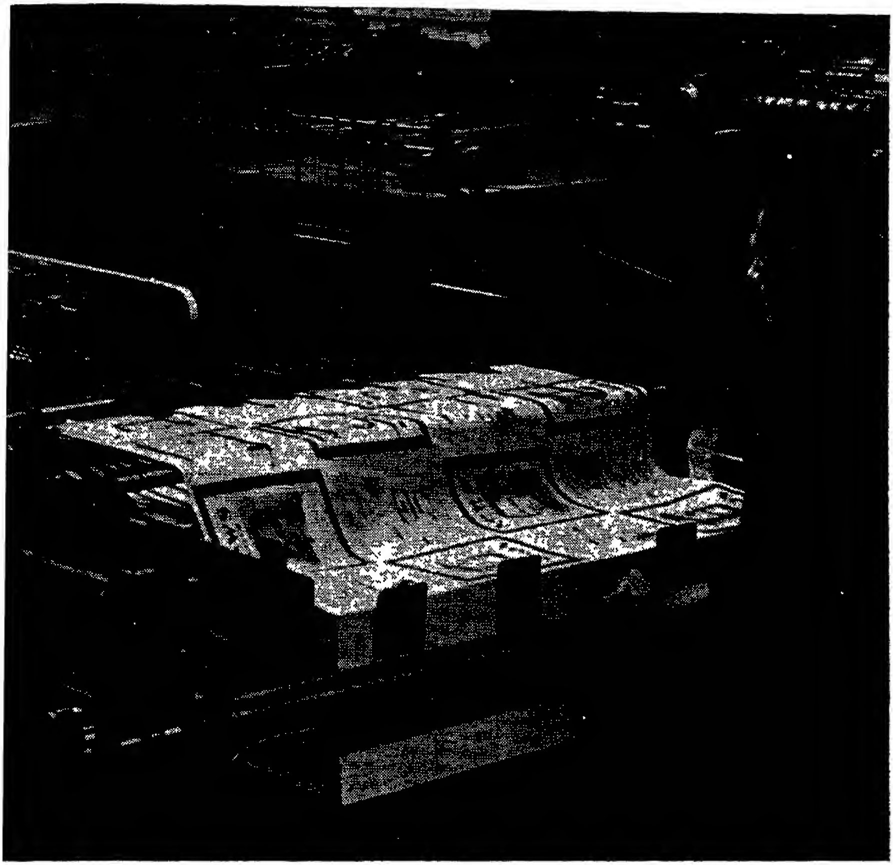
This machine prints a sheet 35 in. × 45 in. on both sides of the paper at the rate of 1,500 copies an hour, it is entirely automatic both as regards the feeding of the white paper, and

we shall meet are merely representative of the many different kinds existing, all performing the same task but each having characteristic movements evolved by its designer. They are made in many sizes from those built to print the small visiting card to those capable of printing a sheet of paper measuring anything up to 60 × 40 in., or even larger.

For newspaper production, or for exceptionally large quantities, "rotaries" are used. On these, type castings (stereo- or electro-plates) revolve in continuous contact with the paper roll, producing any number up to 25,000 an hour. They are most ingenious machines—an assembly of intricate cogs, cams and cylinders which not only print, but cut and fold copies at the same time (Fig. 7).

The small machines are known as "platens." They do not take their impression from cylinders, but print the sheet on a platen surface—the machine opening and closing on the type for each impression.

The machines in the room we are visiting are "flat-bed cylinders," which means that the forme of type is carried



TWO-REVOLUTION PRINTING MACHINE

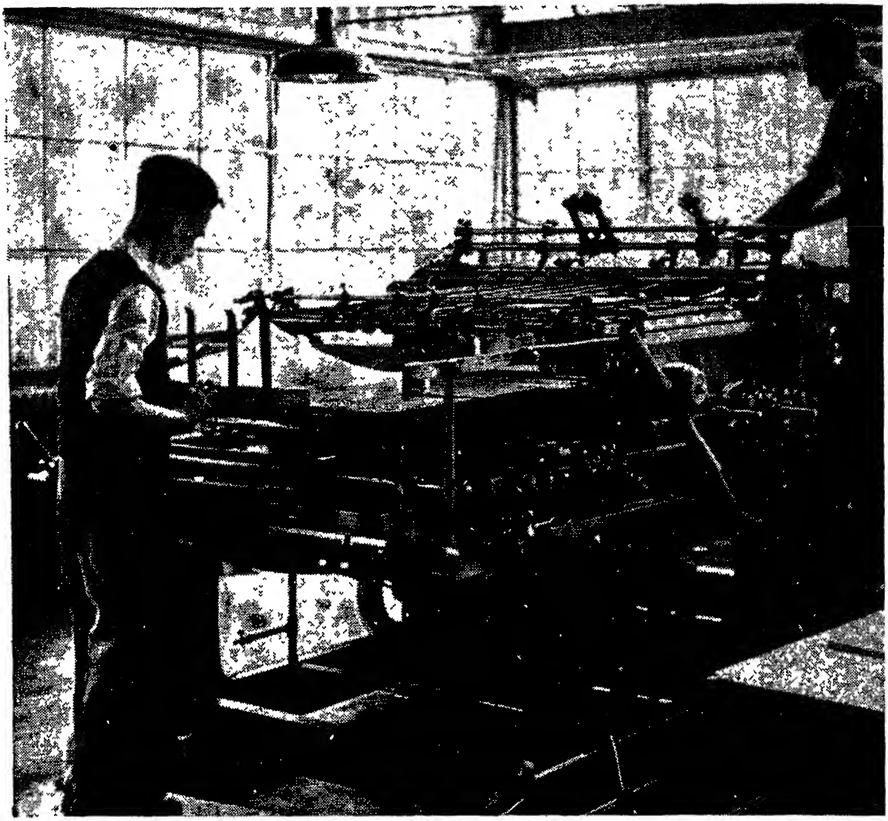
the delivery of the fully printed sheet. The machine-minder must keep constant watch so that minute adjustments can be made to remedy any defects without stopping the run of the machine.

backwards and forwards on a flat-bed carriage and travels beneath a cylinder which is ready for impression.

Here, for example, is a machine having two cylinders on which sheets of paper, 35 × 45 in., are being automatically fed to its grippers. Notice how the grippers take the sheet and carry it round the cylinder that is revolving over the type. One revolution, and one side is printed; after which the sheet is swiftly transferred to a second cylinder upon which the reverse side of the paper is printed from a second forme of type—and all in one continuous movement.

Just look at those perfect sheets flowing over the delivery tapes at the rate of 1,500 copies an hour!

When visiting the composing room we saw an eight-page forme of a magazine being prepared for machining. Well, here is the forme being printed on a suitably sized machine—a Wharfedale, printing a sheet 20 × 30 in. Notice how the forme is securely locked in position on the bed of the machine and how the type comes into contact with those ink-covered rollers which are so adjusted as to convey



TWO-REVOLUTION MACHINE

For general work, a two-revolution printing machine as seen above is widely used. The name derives from the fact that the cylinder makes two revolutions, during one of which the sheet is printed, and during the other the cylinder rises clear of the forme to allow the sheet to be delivered.

a thin film of ink to the type-face.

Just a word about the ink. Here is the supply in this duct at the back of the machine. Printers' ink is of the consistency of heavy treacle. Observe how the roller in contact with the duct carries ink forward to one roller after another until it becomes evenly spread, ready for type.

The cylinder has already been "dressed" to provide correct pressure. Sheets of paper form the "dress" and it is upon these sheets that the operator exercises his skill to make good any imperfection apparent in the type-face.

On this machine the sheets to be printed are fed to the cylinder by hand. The operator will run the machine slowly to allow you to follow the motions. Watch how the inkers do their work, now that the forme is travelling forward beneath the cylinder. Grippers—see those teeth in the sunk slot on the cylinder—close on the edge of the sheet of paper, and as the forme returns, the cylinder, revolving at the same speed as the forme, brings the paper into contact with the type-face. Just sufficient pressure is imparted to produce the printed copy.

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